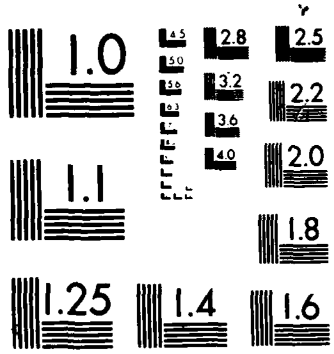
AD-A182 892 DROUGHT CONTINGENCY PLANNING ON FIXED ARMY INSTALLATIONS(U) CONSTRUCTION ENGINEERING RESEARCH LAB (ARMY) CHAMPAIGN IL S W MALONEY ET AL APR 87 1/1

UNCLASSIFIED CERL-TR-N-87/14 F/G 13/2 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

US Army Corps
of Engineers
Construction Engineering
Research Laboratory

USA-CERL TECHNICAL REPORT N-87/14
April 1987
Closed-Loop Water Conservation/
Supply Augmentation Techniques

2

Drought Contingency Planning on Fixed Army Installations

by
Stephen W. Maloney
Hany H. Zaghloul

This report provides information to help Army installations develop a drought contingency plan that reflects an individual installation's specific needs. The various stages of drought are defined to allow installation personnel to recognize the degree to which their water supplies may be reduced. Several water conservation and augmentation strategies that have been used successfully are provided, and guidelines for developing a successful drought contingency plan are outlined. These guidelines provide a basis for estimating emergency water requirements and show ways to assign water use priorities and allocate water supplies.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

AD-A182 592

REPORT DOCUMENTATION PAGE

Form Approved
OMB No 0704 0188
Exp Date Jun 30 1986

1a REPORT SECURITY CLASSIFICATION	Unclassified
1b RESTRICTIVE MARKINGS	
2a SECURITY CLASSIFICATION AUTHORITY	
2b DECLASSIFICATION DOWNGRADING SCHEDULE	
3 DISTRIBUTION AVAILABILITY OF REPORT	Approved for public release; distribution is unlimited.
4 PERFORMING ORGANIZATION REPORT NUMBER(S)	CERL TR-N-87/14
5 MONITORING ORGANIZATION REPORT NUMBER(S)	
6a NAME OF PERFORMING ORGANIZATION	U.S. Army Construction Engr Research Laboratory
6b OFFICE SYMBOL (If applicable)	
7a NAME OF MONITORING ORGANIZATION	
6c ADDRESS (City, State, and ZIP Code)	P.O. Box 4005 Champaign, IL 61820-1305
7b ADDRESS (City, State, and ZIP Code)	
8a NAME OF FUNDING/SPONSORING ORGANIZATION	OACE
8b OFFICE SYMBOL (If applicable)	DAEN-ZCF-U
9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER	
8c ADDRESS (City, State, and ZIP Code)	20 Massachusetts Ave. N.W. Washington, D.C. 20314-1000

10 SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO	PROJECT NO	TASK NO	WORK UNIT ACCESSION NO
4A162720	A896	A	031

11 TITLE (Include Security Classification)

DROUGHT CONTINGENCY PLANNING ON FIXED ARMY INSTALLATIONS (Unclassified)

12 PERSONAL AUTHOR(S)

Maloney, Stephen W. and Zaghloul, Hany H.

13a TYPE OF REPORT	13b TIME COVERED	14 DATE OF REPORT (Year, Month, Day)	15 PAGE COUNT
Final	FROM ______ TO ______	1987, April	70

16 SUPPLEMENTARY NOTATION

Copies are available from the National Technical Information Service
Springfield VA 22161

17 COSATI CODES

FIELD	GROUP	SUB-GROUP
04	02	

18 SUBJECT TERMS (Continue on reverse if necessary and identify by block number)

drought
water conservation
planning
Army installations

19 ABSTRACT (Continue on reverse if necessary and identify by block number)

This report provides information to help Army installations develop a drought contingency plan that reflects an individual installation's specific needs. The various stages of drought are defined to allow installation personnel to recognize the degree to which their water supplies may be reduced. Several water conservation and augmentation strategies that have been used successfully are provided, and guidelines for developing a successful drought contingency plan are outlined. These guidelines provide a basis for estimating emergency water requirements and show ways to assign water use priorities and allocate water supplies.

20 DISTRIBUTION/AVAILABILITY OF ABSTRACT	21 ABSTRACT SECURITY CLASSIFICATION
☐ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT ☐ DTIC USERS	Unclassified

22a NAME OF RESPONSIBLE INDIVIDUAL	22b TELEPHONE (Include Area Code)	22c OFFICE SYMBOL
D. P. Mann	(217) 373-7223	CERL-IMT

DD FORM 1473, 84 MAR

83 APR edition may be used until exhausted
All other editions are obsolete

SECURITY CLASSIFICATION OF THIS PAGE

UNCLASSIFIED

FOREWORD

This research was conducted for the Office of the Assistant Chief of Engineers (OACE), Headquarters, U. S. Army Corps of Engineers (HQUSACE), under Project 4A162720A896, "Environmental Quality Technology"; Task A, "Installation Environmental Management"; Work Unit 031, "Closed-Loop Water Conservation/Supply Augmentation Techniques." The work was conducted by the Environmental Division (EN), U. S. Army Construction Engineering Research Laboratory (USA-CERL). The HQUSACE Technical Monitor was Mr. Tom Wash (DAEN-ZCF-U).

Dr. R. K. Jain is Chief of USA-CERL-EN. COL Norman C. Hintz is Commander and Director of USA-CERL, and Dr. L. R. Shaffer is Technical Director.

CONTENTS

CONTENTS (Cont'd)

FIGURES

TABLES

DROUGHT CONTINGENCY PLANNING ON FIXED ARMY INSTALLATIONS

1 INTRODUCTION

Background

Drought is a complex concept because it is a function of both meteorologic conditions and natural or manmade hydrologic features. A useful definition of drought is "a period during which streamflows are inadequate to supply established uses under a given water-management system."[1] Water management systems refer to dams and reservoirs, groundwater infiltration basins, and aqueducts used to control river flow, replenish aquifers, or transport water between hydrologically disconnected regions.

The interplay between streamflow (quantity of input), water management (e.g., reservoirs, infiltration basins) and water demand (required output) suggests that with sufficient management, droughts should never exist. However, in some regions where evaporation exceeds average annual rainfall, no amount of management could provide enough water for large demands. Thus, the real consideration becomes economical water management. In Los Angeles, water is imported from hundreds of miles away via aqueducts to the north (the California Aqueduct and the Los Angeles Aqueduct) and east (the Colorado Aqueduct). Surface water on the east coast of the United States may also travel great distances by natural waterways rather than manmade structures.

Most water management structures (e.g., dams, reservoirs, aqueducts) aimed at augmenting dependable, year-round water supplies require years of planning, development, and construction. Shorter-term projects, such as reuse of wastewater for irrigation or development of new (deeper) well supplies, also require major construction. Thus, even though drought develops slowly, the time required for supply augmentation exceeds the warning. Furthermore, it is difficult to allocate public monies for water supply development when water shortages do not exist. Therefore, it is essential to plan for drought, so that its effects can be mitigated. When capacity to meet critical demands under certain drought conditions is shown to be insufficient, the plan can be used to justify water supply improvements, even during "wet" years.

Like civilian communities, the Army must also plan for water shortfalls, especially those that might occur during mobilization. The Army has many options that derive from the mobilization mission available for fixed installations. Mobile field units, including the ERDLATOR, ROWPU, SMFT and TWDS* can be used to augment existing water supplies and to store and distribute water. Training modifications must be considered when the potential for forest fires increases. Conservation is crucial, both in allocating limited resources and in gaining the cooperation of adjacent communities. Cooperation and good public relations are also needed to gain additional water supplies through interconnections and temporary reallocation of water rights. These aspects of water use planning are only a few of the things to be considered in developing an installation

---

[1] R. K. Linsley, M. A. Kohler and J. L. H. Paulhus, *Hydrology for Engineers*, 2nd ed. (McGraw-Hill Book Company, 1975).

*ROWPU = Reverse Osmosis Water Purification Unit; SMFT = Semi-Trailer Mounted Fabric Tank; TWDS = Tactical Water Distribution System.

drought contingency plan. To achieve a workable plan, military personnel must be aware of many different types of water conservation strategies and supply augmentation techniques. Furthermore, this information must be incorporated into a plan that is well organized, easy to implement, and suited to the individual installation's unique location, climate, and mission.

Objective

The objectives of this report are to (1) define stages of drought emergency, (2) outline water conservation strategies and supply augmentation techniques for use during drought, and (3) provide guidelines for developing an installation drought plan.

Approach

The various stages of drought were defined, and methods of forecasting the occurrence and degree of drought were outlined. Several strategies that have proved successful for conserving water and for augmenting water supplies were described. Finally, an outline for developing an Army installation drought plan was presented that provides checklists and guidelines for estimating water demands and setting use priorities.

Scope

The techniques described in this report apply to fixed Army installations that own and/or maintain potable water systems or any portion of a water system (i.e., wells, surface water plants, ground or elevated reservoirs, distribution systems, pumping stations).

Mode of Technology Transfer

It is recommended that the information in this report be incorporated into an Engineer Technical Note.

2 DROUGHT STAGES

Water conservation planning involves estimating demands and resources, examining resource management/augmentation techniques, and allocating resources to the demands. Planning also involves feedback, which is generated by implementing the plan and observing its effectiveness, then "feeding back" any changes that may improve its operation. Thus, common operations that are implemented regularly have the advantage of being "fine-tuned."

Drought planning follows the same methodology, but the more extreme cases of drought are rare, so planning is both more difficult and more necessary. Recovery from drought is both slow and uncertain--conditions that can amplify the effects of improper planning. Figure 1 outlines the methodology of drought planning. Each portion of this figure is discussed in detail in this report.

Definition of Drought

Defining drought is the first consideration. Drought is a relative term in which geographic location is the most important criterion. Some examples[2] will show the diversity of the definition. On the island of Bali, 6 days without rain is considered a drought. At the other extreme is Libya, where drought conditions are officially acknowledged only after 2 years without rain. Before the Aswan Dam became operational in Egypt, failure of the Nile River to flood constituted a drought, regardless of the amount of local rainfall.

In this report, a drought is defined as a period during which existing water supplies are inadequate to supply established uses under a given water management system. This is a slight modification of Linsley's definition[3] designed to incorporate supplies wholly or substantially derived from groundwater sources. This definition emphasizes the need for feedback and planning. A drought is not determined solely by water supplies, but also by the water management system. Although one cannot control water supplies, one can modify water management systems over the long term. In the short term, one can be forced to modify "established uses."

Army installations in the Continental United States (CONUS) are not large enough to occupy a complete watershed. Therefore, outside agencies (for example, the Delaware River Basin Commission) have already defined drought for areas in which high levels of water use (and consequently, water management) occur.

Installations should first identify the basin in which they are located and then determine if there is a river basin commission for that area by contacting the local office of the U.S. Geological Survey. Installations in sparsely populated areas that supply their own water and are the only significant user in that watershed may have to develop their own definitions of drought, using the examples given in this report as a model. Figure 2 shows the major river basins in the United States.

---

[2] John A. Dracup, "Causes and Occurrences of Drought," *Drought Management and Its Impact on Public Water Systems* (National Academy Press, 1986).
[3] Linsley, Kohler, and Paulhus.

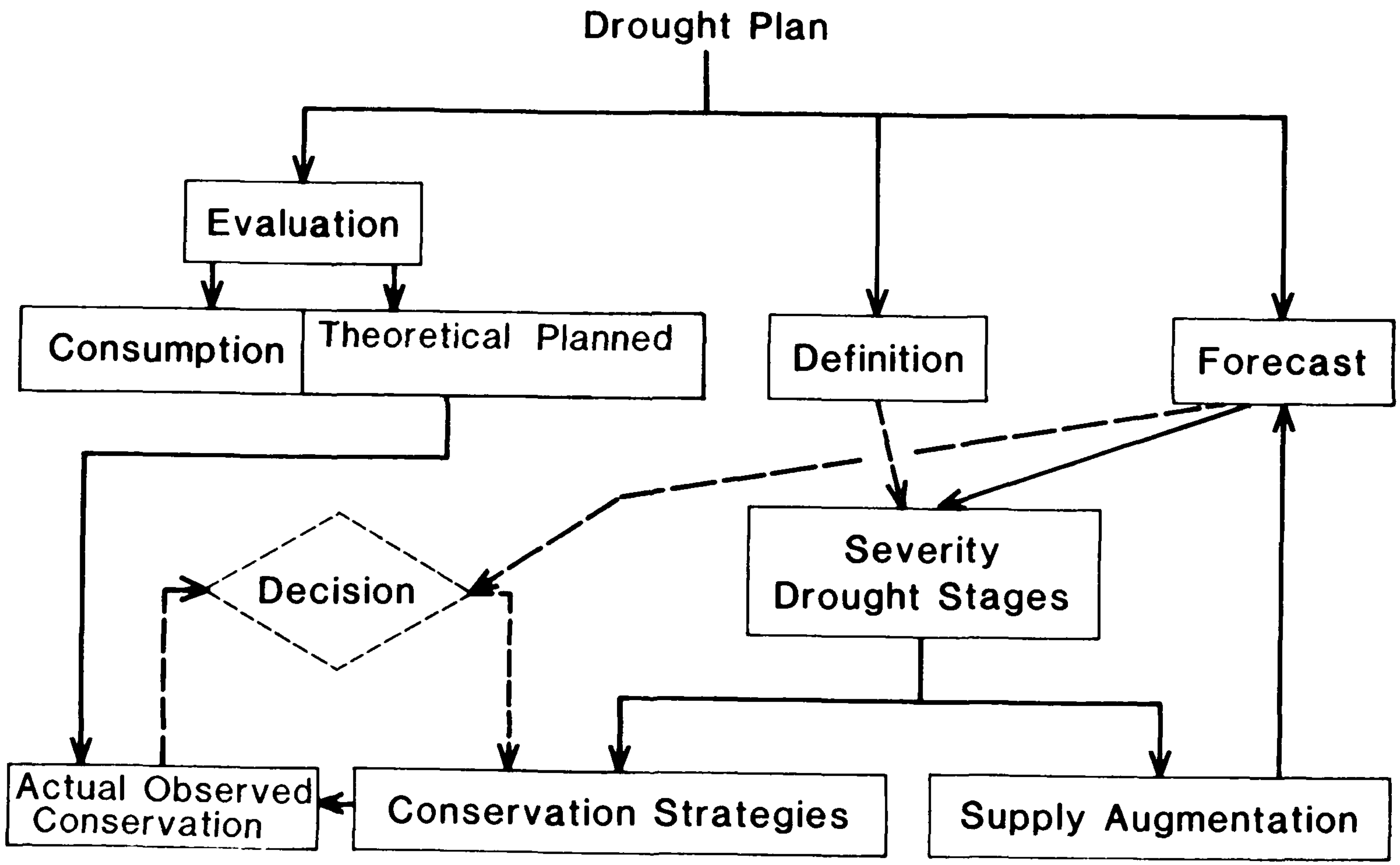


Figure 1. Drought planning schematic.

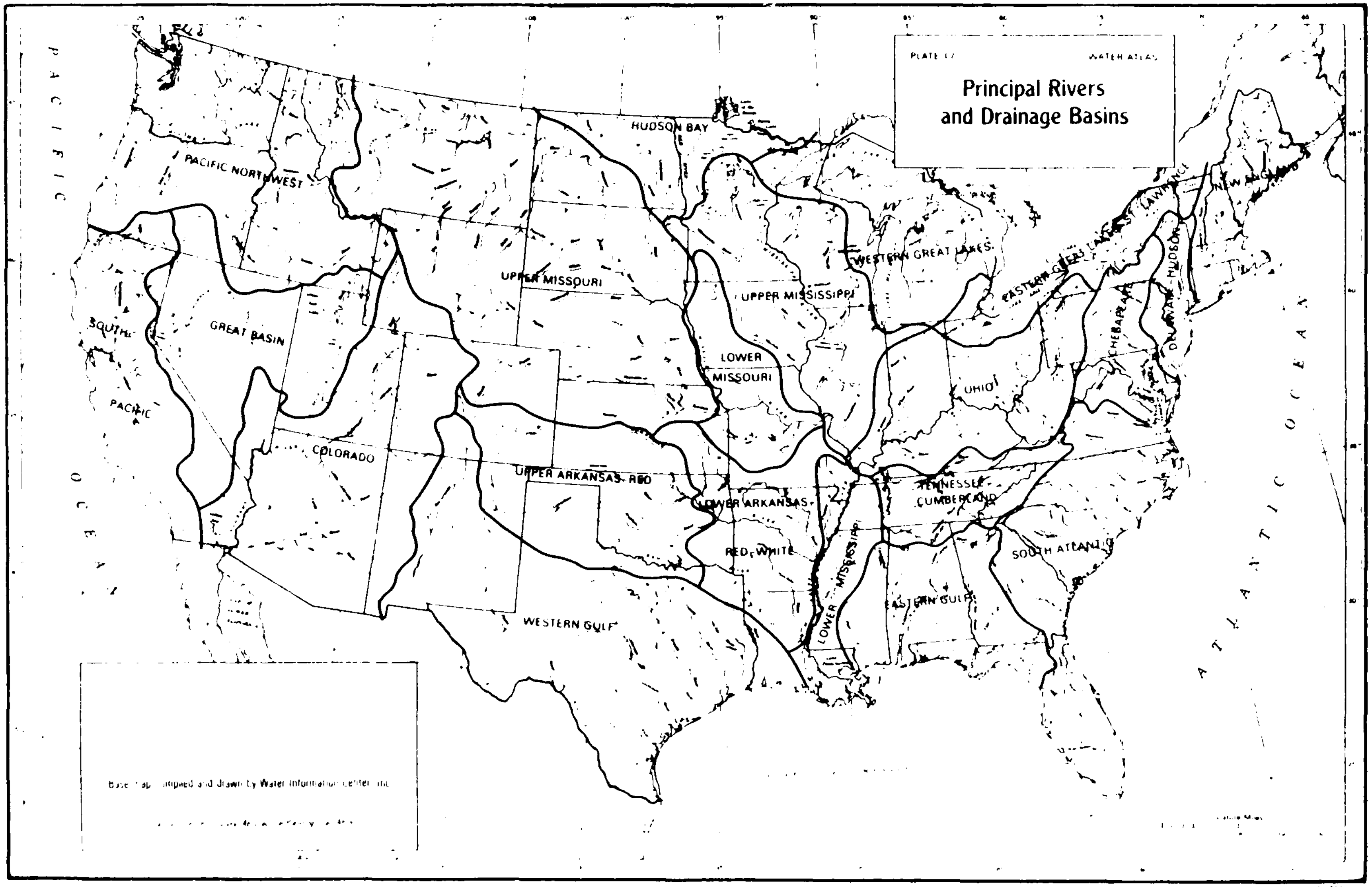


Figure 2. Major river basins of the United States.

Measures of Drought

Another way to interpret drought events is by considering the relationship between deficit of water supply and duration of the deficit. Dracup[4] uses a mathematical expression to define the magnitude of a drought. The equation relates magnitude (M) to the ratio of water supply deficit (severity, S) to time (duration, D) as follows:

$$M = S/D \tag{Eq 1}$$

This can also be shown graphically as a continuous classification of hydrologic events as shown in Figure 3. Here, floods and droughts are shown opposite each other, separated by regions characterized as high flow or low flow.

Estimating the magnitude of a drought from this equation requires a complete knowledge of how rainfall affects streamflow or the groundwater table. As a conceptual tool, it is most useful to visualize the effects of drought. Since precise relationships between precipitation and water supply are hard to determine, drought stages are usually assessed based on the remaining water supply and on historical data on the replenishment of the water supply. Such data include reservoir level, groundwater table elevation, or streamflow, rather than recent precipitation data.

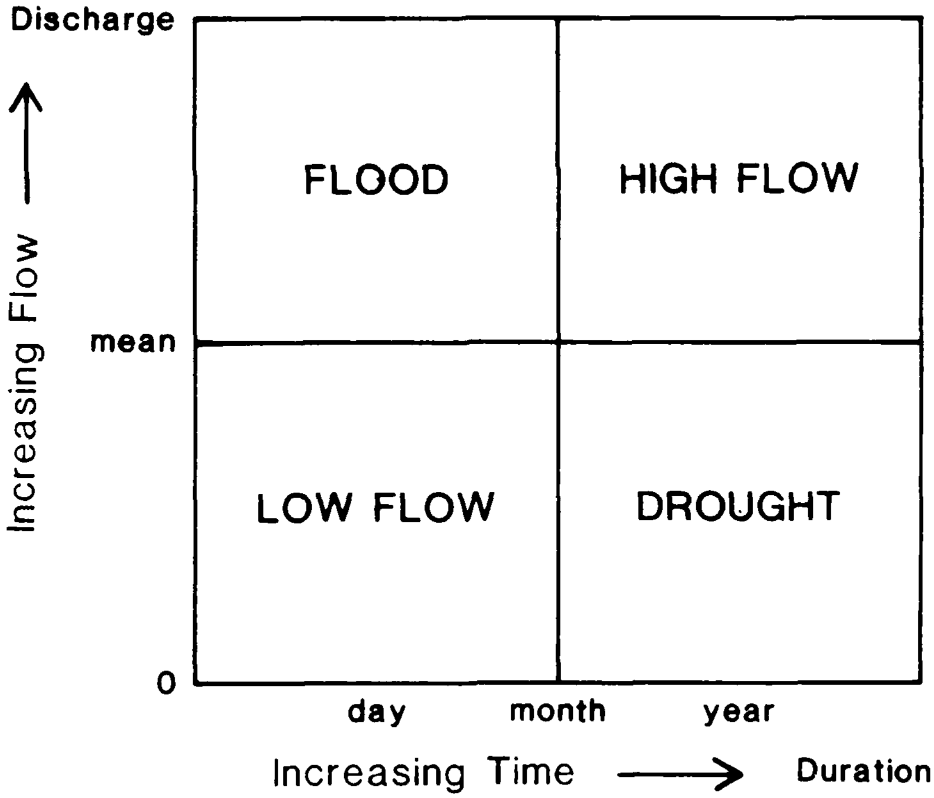


Figure 3. Classification of hydraulic events.

[4]John A. Dracup, et al., "On the Statistical Characteristics of Drought Events," *Water Resource Res.*, Vol 16, No. 2 (April 1980), pp 289-296.

Drought Stages

The slow development of a drought allows several anticipated levels or stages to be defined. Stages are anticipated based on historical records of three drought severity factors: precipitation, runoff, and use. Drought stages are classified in conjunction with measures of supply as well as the expected drought forecast (Figure 1). The following sections describe conventional drought stages.

Normal Conditions

The normal or base condition in any region is the result of average, long-term precipitation. Many factors determine how precipitation will affect the water supply. The degree to which water supply augmentation techniques are implemented is an important consideration that makes it impossible to define strict drought vs. precipitation relationships and that also makes it inappropriate to compare geographically different regions. For example, a drought on the east coast could be considered a wet year in southern California.

Thus, the establishment of base conditions is essential to predicting drought severity. Planning agencies must monitor and appraise supply/demand status as well as estimate the effect of projected changes on the supply/demand ratio during a drought. Projected changes result from the demands of significant new construction, such as a power plant requiring cooling water. These demands should be considered in the contingency planning process, and the planning agency must have review authority over water supply allocations.

Drought Alert

The declaration of a "drought alert" stage has been conventionally adopted when the indications that about 70 percent or less of normal seasonal capacity has been reached. Normal seasonal capacity involves projecting anticipated replenishment to water sources as well as projecting demands. Thus, this condition is 70 percent or less of the base water supply.

In this stage, drought actions are initiated by reviewing drought contingency plans and noting any significant recent supply/demand changes. Army installations would generally not issue, but rather receive, a drought alert. Regional planning agencies would issue alerts, but installation personnel should be familiar with the plans and provide input regarding changing water demands.

Drought Warning

This stage, which occurs when water supplies fall below 50 percent of seasonal capacity, is the first level at which planned actions are taken. General conservation techniques suggested during the drought alert stage are now enforceable. Also, planning agencies must more closely monitor and appraise drought status to prepare for the next stage.

During a drought warning, Army installation personnel must be prepared to implement conservation methods. Prior preparation would include a plan to reduce or eliminate nonessential water use (e.g., car washing by individuals, lawn watering), and to prepare public announcements regarding drought progress. Due to the development of infrastructure in the United States, a drought may not be apparent (e.g., water pressure does not decline, irrigated areas do not show signs of water shortage). Therefore, informing installation personnel is a critical mission of Army drought plans.

Drought Emergency

A "drought emergency" is usually declared when water supplies fall below 35 percent of normal seasonal capacity. This is a critical stage during which more water restrictions must be imposed and emergency sources (if available) and equipment used. Drought procedure plans for deficiencies and conservation efficiency reports should be reviewed weekly.

At this level, installation personnel must implement strict water conservation policies and establish procedures for their enforcement. Coordination of conservation efforts must be channeled throughout the command structure and responses/instructions centralized in an emergency operations center.

Drought Disaster

If the situation continues to deteriorate, emergency procedures must be enacted and emergency orders issued if required. Appropriate "worst case" options must be implemented and very tight water use measures put into effect.

3 FORECASTING DROUGHT

Forecasting any event requires accurate knowledge of a cause and effect relationship. Short-term weather forecasting has recently progressed a great deal; the development and path of a hurricane can now be monitored, and the possibility of severe weather can be predicted from movement of air masses. Tornado forecasting is much less accurate; conditions conducive to a tornado can be observed and reported, but actual occurrence cannot yet be predicted.

Drought prediction is even less precise. Most forecasting techniques have been developed for the short-term prediction of severe weather; long-term weather forecasting has not been developed as rapidly. Generally, there is statistical evidence that hot, dry summers follow hot/warm springs over the plains of the United States, and these conditions tend to persist from one year to the next.

Forecasting drought is based on either meteorological or hydrological principles; however, neither method has been very successful so far. The following sections describe five drought indicators currently in use in different parts of the nation.

Palmer Index

The Palmer Index, which is designed to indicate drought severity, is based on the magnitude and duration of moisture deficiency, and considers supply and demand. The index is based on long-term records of temperature and precipitation. It measures the balance between precipitation and stored soil moisture, along with natural factors that deplete water supplies, such as evapotranspiration. The index is then weighted by a climatic factor.

The result is a numeric value that represents a deficit or excess which expresses moisture conditions for a specific area at a specific time. An index of 1.0 to -1.0 is considered normal, while an index reading of -2.0 to -4.0 represents moderate to severe droughts.[5]

Information about the Palmer Index may be obtained from the National Weather Service via a computer link. Access to the computer program is currently free for Federal installations. The program is completely menu-driven, and allows 46 choices, including a Help function that defines the keywords. "Help" is accessed by entering the number 6. Figure 4 shows a sample sign-on session. To use the program, the terminal should be set up as follows:

Full duplex
Eight data bits
No parity
Two stop bits
300 or 1200 baud.

[5] M. S. Hrezo, et al., "Managing Droughts Through Triggering Mechanisms," *Journal of the American Waterworks Association*, Vol 78, No. 6 (June 1986), pp 46-51.

```
PLEASE TRY AGAIN

PLEASE TRY AGAIN
NWS                 CAC/NMC/NWS/NOAA
   FOR INFORMATION OR HELP WITH THIS SYSTEM  PHONE MR FULWOOD
  OR MRS DIONNE (301)763-8071.

   **** NOTICE *** NOTICE *** NOTICE *** NOTICE ***

  PRECIPITATION DATA FOR THE PAST 8 WEEKS ARE AVAILABLE FOR MANY
  NEW LOCATIONS USING THE OPTION "HIDYPRCP".


  PLEASE LOGOFF(GOODBY OPTION MAIN MENU) BEFORE HANGING UP!!!

  PHONE NUMBERS (301)899-0829 AT 300 BAUD AND (301)899-0747 AT 1200
  BAUD ARE AVAILABLE. THESE NUMBERS WILL PUT YOU ON A BACKUP COMPUTER
  AND MAY BE USED IF THE PRIMARY SYSTEM IS INOPERABLE OR BUSY.

  ***************************************************************


ENTER PASSWORD: USACERLP
                        NOAA AUTOMATED OFFICE SYSTEM

 GOODBYE  -  0
 CLIMRANK -  1 MSAHDDY  - 17 WCTYTEMP - 32
 DDAYEXP  -  2 PASTDATA - 18 WFOREIGN - 33
 FORECAST -  3 PPDANOTE - 19 WPDANOTE - 34
 GLOBAL   -  4 PPDCENTR - 20 WPDCENTR - 35
 GRODGREE -  5 PPDEAST  - 21 WPDEAST  - 36
 HELP     -  6 PPDSOUTH - 22 WPDSOUTH - 37
 HIDYPRCP -  7 PPDWEST  - 23 WPDWEST  - 38
 MAPS     -  8 SCTYPRCP - 24 WSACDDY  - 39
 MCTYCDDY -  9 SCTYTEMP - 25 WSAHDDY  - 40
 MCTYHDDY - 10 SELECT   - 26 WXCLSMYI - 41
 MCTYPRCP - 11 WAPTDAT  - 27 WXCLSMYM - 42
 MCTYTEMP - 12 WAPTDOC  - 28 WXCLSMYS - 43
 MFOREIGN - 13 WCTYCDDY - 29 WXCLSMYU - 44
 MRECPRCP - 14 WCTYHDDY - 30 WXCPSMYH - 45
 MRECTEMP - 15 WCTYPRCP - 31 WXCPSMYI - 46
 MSACDDY  - 16

ENTER MENU NUMBER & PRESS RETURN  0
GOODBYE, PLEASE HANG UP TELEPHONE
```

Figure 4. Sample sign-on procedure for Palmer Index from the National Weather Service.

There are two telephone numbers, depending on which baud rate is chosen. Use 301-899-0825 for 300 baud and 301-899-0830 for 1200 baud. After making the computer link, hit [Enter] or [Return] and wait for the host computer to reply with the prompt "PLEASE TRY AGAIN." This prompt is shown twice in the sample sign-on session. Respond with NWS (in upper-case letters). All input required by the operator in the sample sign-on session is shown underlined in Figure 4. After the basic system information and any notices are printed, the host computer will ask for the password.

The password for this program is USACERLP. Both NWS and USACERLP are typed in capital letters. After gaining access to the program via the password, the operator need only answer the questions posed by the menu-driven program. The sample session shows the main menu; for this session, the option 0, for session termination, was selected. Figure 5 shows the output obtained if one of the Palmer Index databases is selected. In this case, 35 is entered instead of 0 after the main menu is accessed. The data are arranged by climate region and by state. Figure 6 is a map of climate regions. After the required information (i.e., Palmer Index values) is obtained, the user exits the system through the menu.

Precipitation

Lack of precipitation is the underlying cause of most droughts. The lack of precipitation must occur throughout an entire watershed and, most important, must occur in the region of natural or manmade water management systems. If recharge areas of the water management system have had substantial rainfall, a portion of a watershed may undergo prolonged drought conditions without triggering any stage of drought alert. An example is southeastern Pennsylvania, a region that uses large amounts of surface water for potable supplies. The actual recharge area, which is hundreds of miles to the north, feeds reservoirs on the Delaware River. Thus, a drought in the recharge area of New York is more critical to the water supply of major cities in southeastern Pennsylvania than a local drought. This problem can also lead to public confusion and disbelief if the local area is not having a severe drought, but water restrictions are imposed due to a drought in the recharge area.

A precipitation deficit in the winter and spring, when large reservoirs normally refill, can severely impact public water supplies. A precipitation deficit in the summer growing season is critical for agricultural crops. All other drought indicators are completely or partly dependent on precipitation. Both the magnitude and duration of deficits are used for comparison with data from preceding consecutive months.

Figure 7 shows an example of precipitation deficit use. The example is based on calculations for an area of New York. There are 26 rain gauge stations in six regions throughout the state. For each region, the precipitation deficit is calculated monthly and averaged for each region. If there was surplus precipitation, the deficit is negative. The calculated deficits are then plotted as inches of deficit versus months. Also plotted are straight lines representing deficits as a percentage of mean annual precipitation. The percentages used are:

10 - Beginning of alert
20 - Beginning of warning
30 - Beginning of emergency
40 - Beginning of disaster

WEEKLY PALMER DROUGHT AND CROP MOISTURE DATA
FOR THE CLIMATE DIVISIONS IN THE CENTRAL REGION
CLIMATE ANALYSIS CENTER-NMC-NWS-NOAA
WEEK 17 OF THE 1986 GROWING SEASON
ENDING JUNE 28, 1986

ST	CD	TMP (F)	PRCP (IN)	SOIL MOISTURE UPPR LAYR (IN)	SOIL MOISTURE LOWR LAYR (IN)	PCT FLD CPC END WEEK	POT EVAP (IN)	RUN OFF (IN)	CROP MOIST INDEX	CHNG FROM PREV WEEK	MONTH MOIST ANOML (Z) INDEX	PRELIM-P FINAL -F PALMER DROUTH INDEX	PRCIP NEED TO END DROUTH (IN)
CO	1	73	0.2	0.0	0.36	5	1.28	0.0	-1.65	-0.72	-0.15	-3.50 P	4.61
CO	2	69	0.2	0.0	2.35	34	1.17	0.0	-1.21	-0.15	-2.21	-2.17 P	2.15
CO	3	73	0.2	0.0	0.65	8	1.28	0.0	-0.88	-0.93	-0.41	-1.49 P	2.11
CO	4	68	0.1	0.0	1.55	22	1.13	0.0	-1.34	-0.57	-1.35	-2.78 F	3.34
CO	5	61	0.3	0.0	2.24	32	0.97	0.0	0.24	0.08	1.03	4.24 P	
IL	1	72	1.6	0.41	9.00	94	1.25	0.0	0.48	0.35	0.61	-0.65 P	0.45
IL	2	70	1.6	0.43	8.62	90	1.17	0.0	0.48	0.44	0.37	-1.04 P	1.39
IL	3	75	1.0	0.0	7.65	76	1.33	0.0	-0.06	0.02	-0.97	-1.76 P	4.07
IL	4	73	1.6	0.36	8.85	92	1.24	0.0	0.50	0.19	1.39	-1.16 P	2.10
IL	5	72	1.3	0.08	8.81	89	1.22	0.0	0.21	-0.24	1.37	1.93 P	
IL	6	77	0.4	0.0	6.45	64	1.41	0.0	-0.51	-0.27	-1.32	-2.06 P	5.23
IL	7	74	0.5	0.0	5.12	57	1.26	0.0	-0.67	-0.25	-1.10	-2.16 F	5.79
IL	8	78	0.0	0.0	5.28	59	1.44	0.0	-0.83	-0.50	-2.16	-1.37 P	3.30
IL	9	77	0.0	0.0	5.34	59	1.39	0.0	-0.80	-0.48	-1.94	-1.35 P	3.01
IN	1	70	1.1	0.0	7.98	89	1.16	0.0	0.13	0.04	0.25	-1.22 P	2.23
IN	2	69	1.3	0.32	8.00	92	1.13	0.0	0.29	0.20	1.47	0.55 P	
IN	3	69	1.4	0.98	8.00	100	1.13	0.0	0.42	0.10	2.68	1.46 P	
IN	4	71	0.5	0.0	7.20	80	1.17	0.0	-0.03	-0.08	-0.71	-0.69 P	0.70
IN	5	72	0.3	0.0	6.95	77	1.21	0.0	-0.10	-0.15	-1.25	2.49 P	
IN	6	71	0.3	0.0	6.97	77	1.19	0.0	-0.11	-0.20	-0.56	-0.98 F	1.58
IN	7	74	0.0	0.0	6.59	73	1.26	0.0	-0.15	-0.24	-0.71	-1.39 P	3.03
IN	8	74	0.1	0.0	6.33	70	1.26	0.0	-0.35	-0.30	-1.60	-1.61 F	3.74
IN	9	74	0.1	0.0	5.90	66	1.27	0.0	-0.56	-0.36	-1.93	-1.94 F	4.90
IA	1	74	1.0	0.0	7.74	77	1.36	0.0	0.09	-0.12	-1.23	3.51 P	
IA	2	73	0.7	0.0	7.70	77	1.30	0.0	-0.08	-0.11	-2.44	-0.92 P	1.13
IA	3	71	0.5	0.26	9.00	93	1.24	0.0	0.15	-0.37	-0.22	1.95 P	
IA	4	77	2.3	0.83	8.36	92	1.47	0.0	0.96	0.60	0.22	2.66 P	
IA	5	75	2.9	1.00	9.00	100	1.37	0.90	1.86	1.56	1.22	2.73 F	
IA	6	73	2.5	1.00	9.00	100	1.29	0.63	1.37	1.21	1.34	2.60 F	
IA	7	80	1.1	0.0	7.05	70	1.61	0.0	-0.14	-0.02	-1.88	1.78 P	
IA	8	78	1.2	0.0	7.02	70	1.47	0.0	-0.15	0.10	-1.74	1.74 P	
IA	9	76	1.5	0.10	8.25	84	1.40	0.0	0.22	0.16	-1.04	1.70 P	
KS	1	77	0.5	0.0	3.15	29	1.41	0.0	-0.67	-0.29	-1.10	-1.22 P	2.12
KS	2	79	0.7	0.0	6.91	69	1.49	0.0	0.32	-0.03	-0.74	1.55 P	
KS	3	81	1.0	0.0	6.39	64	1.64	0.0	-0.44	-0.01	-1.94	2.64 P	
KS	4	79	1.0	0.0	0.60	7	1.50	0.0	-1.19	0.73	-1.03	-3.00 P	7.67
KS	5	80	1.0	0.0	4.70	59	1.58	0.0	0.33	0.11	-0.87	1.86 P	
KS	6	79	0.9	0.0	3.62	52	1.47	0.0	-0.78	-0.01	-2.15	2.02 P	
KS	7	79	0.7	0.0	0.75	8	1.49	0.0	0.00	-0.03	1.22	-1.61 P	2.97

Figure 5. Sample output for Palmer Index values from the National Weather Service.

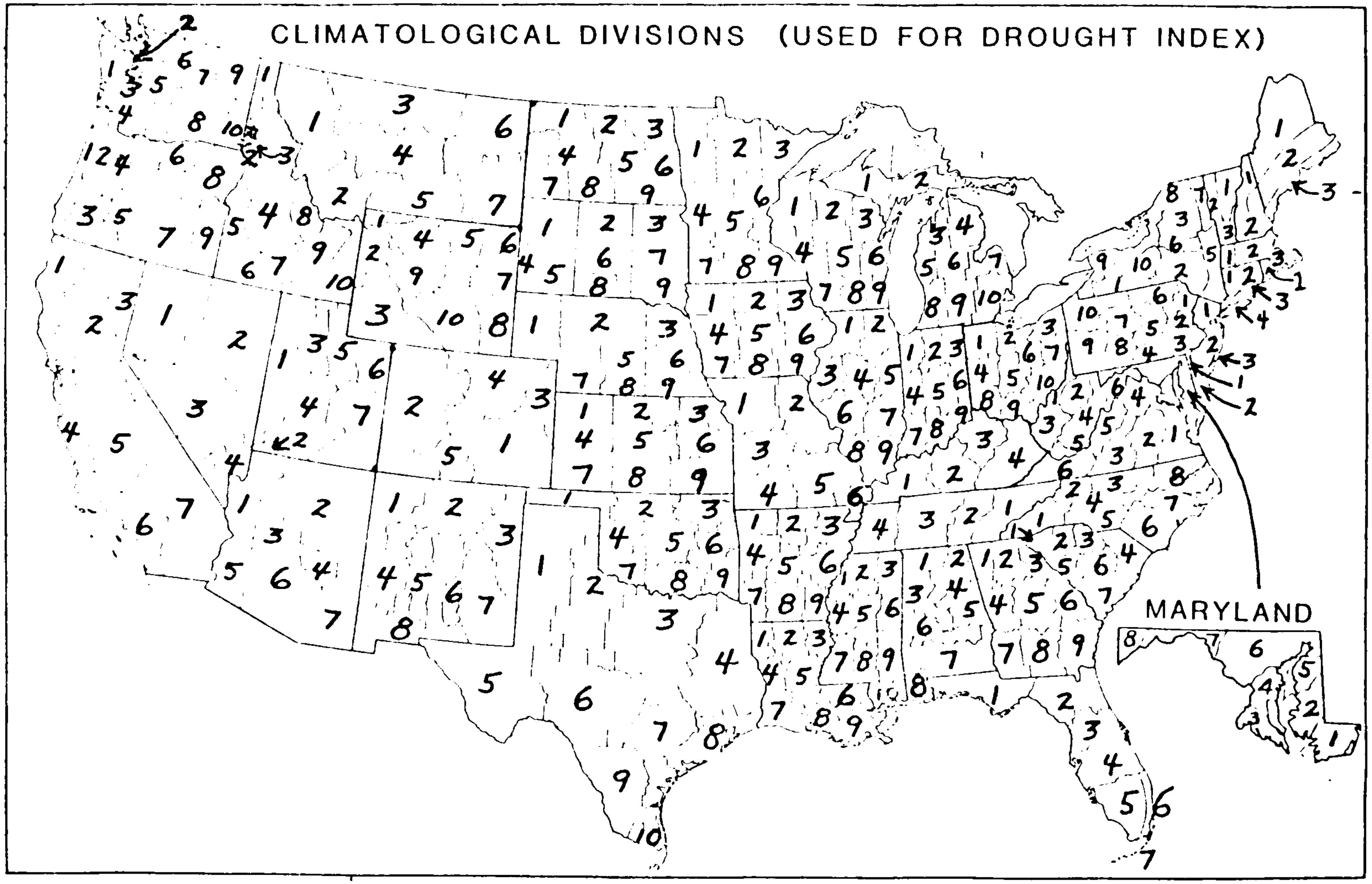


Figure 6. Map of climatological divisions for drought index.

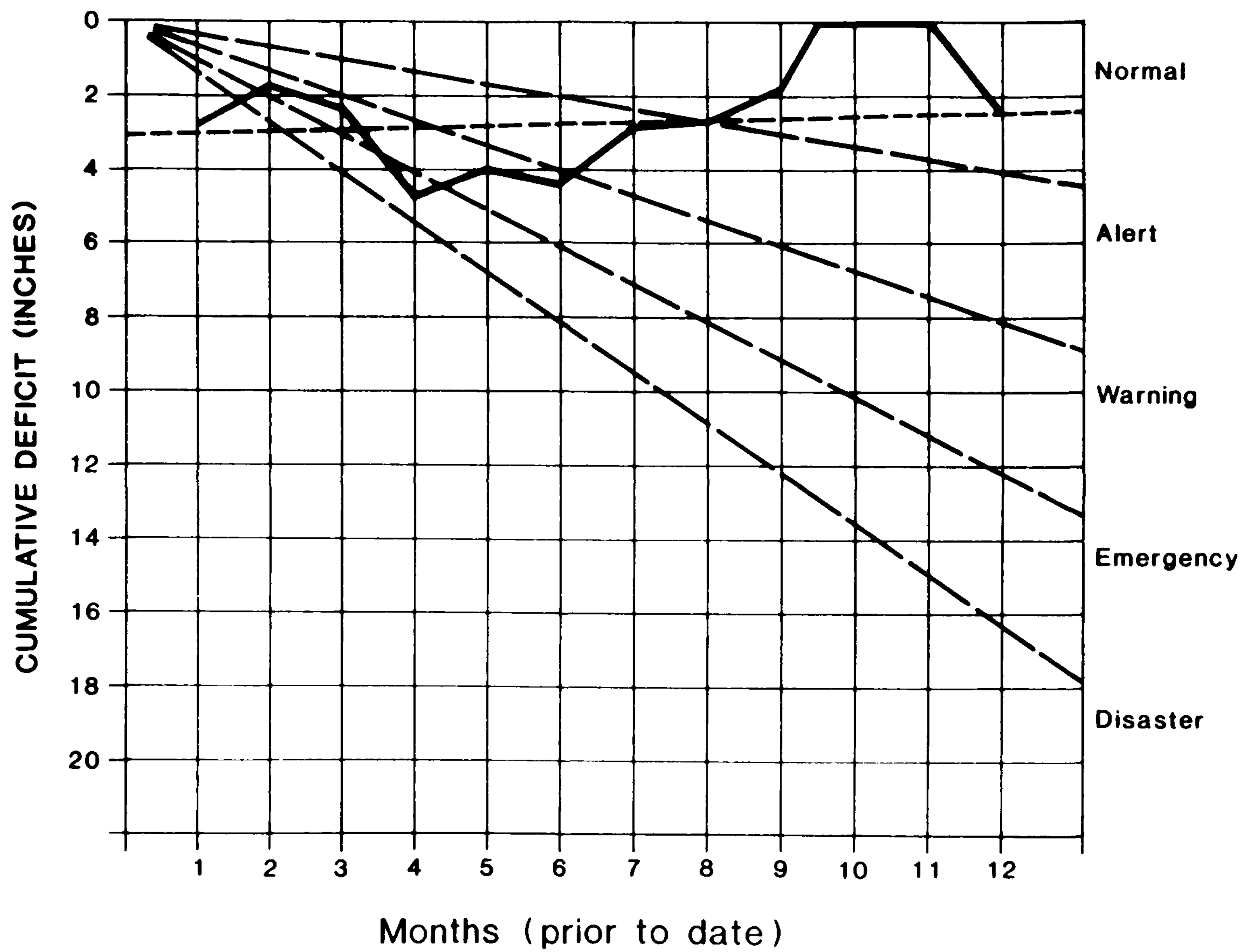


Figure 7. Example of cumulative precipitation deficit chart.

The trend of the line plotted from the deficits, using a best fit procedure such as least squares, is then used to determine the region of the graph in which the trend lies. This is a long-term procedure requiring 12 months of data. If the best fit line falls between the boundaries of the 20 percent and 30 percent lines, then the area is in a "drought warning" stage. The trend of the data shown in the example is greater than normal precipitation, indicating a "no drought" stage at the time these data were collected.

Reservoir/Lake Storage

Reservoir storage is considered a leading indicator for water supply systems relying on surface storage. The method compares current storage with normal or historical storage, and also considers the reservoir's storage/drain characteristics. The same method is used for lake-level comparisons. Estimating the number of days of water supply remaining in the reservoir is another commonly used method.

With the aid of models and computer systems, simulation studies can be made of reservoir/lake operations to determine storage patterns for different conditions. In the State of New York,[6] when the reservoir levels on the watch list fall into the alert-warning stage, drought conditions will be monitored for all community water systems in that region and their status taken into account in determining the drought status.

Figure 8 shows the relationship between reservoir/lake level and the drought stage as developed for the reservoirs in New York. The example is the combination of the Cannonsville, Pepacton, and Neversink Reservoirs. The percent of storage in the figure refers to the percent for the entire combined capacity of all reservoirs, not each reservoir separately. These reservoirs constitute a major water management system, and are operated together to maximize benefits. As shown, relatively low levels of water, down to 50 percent of capacity, are acceptable as normal during October and November. The acceptance line rises sharply thereafter, when snowmelt and spring rains are expected to fill the reservoirs for peak summer demands.

Streamflow

Streamflow is another indication of normal versus subnormal water supply conditions. Streamflow is made up of both surface runoff and groundwater discharge to streams. Under drought conditions, the major component may be the base flow from groundwater. If substantial amounts of groundwater are being withdrawn in the area of a surface stream, the stream may be recharging the groundwater table, which further reduces available streamflow.

Flow frequency curves are based on historical values determined from stream gauges. There is natural variation in streamflow during the year, so drought severity estimations should be based on comparisons of several years of data for the same month (or season). Flow frequency curves show the probability of flow magnitudes being equalled or exceeded based on the period of record at a particular stream-gauging station. Annual, seasonal, or monthly flow frequency curves may be developed.

[6] *New York State Drought Preparedness Plan* (New York State Drought Management Task Force, February 1981).

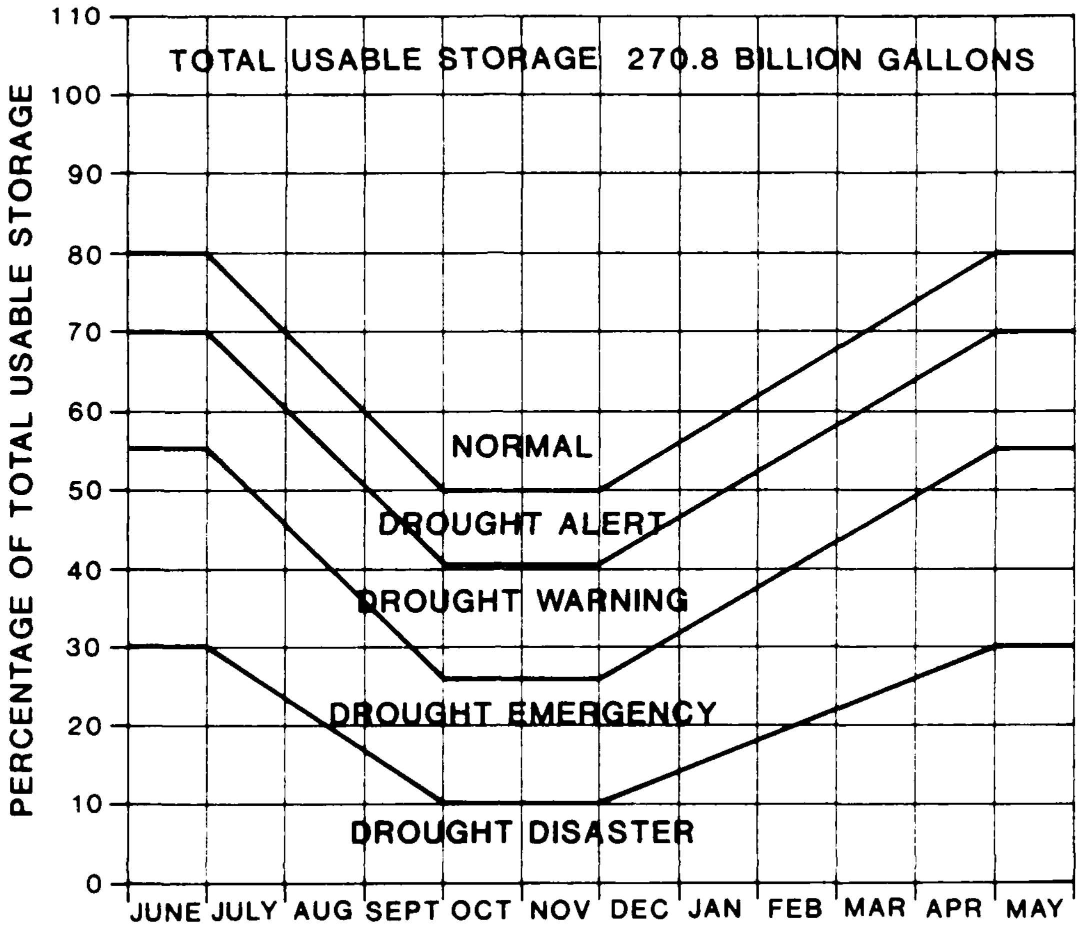


Figure 8. Example rule curves for reservoir/lake drought stages for the State of New York.

Monthly flow duration curves appear to be the most useful.[7] Flows that are equalled or exceeded up to 75 percent of the time are considered normal. The U.S. Geological Survey maintains an extensive network of stream-gauging stations throughout the country, which can serve as index stations for monitoring current streamflow conditions. If a drought stage is indicated, monitoring can be expanded to include additional stations in the region. For New York City, cumulative reservoir inflow for preceding 6-month periods are used to supplement reservoir storage criteria to improve the capability of determining approaching drought conditions. More weight is given to the storage factor. An additional factor in this method is the water content of the snow cover over the region's watershed during the winter and early spring.

Figure 9 is an example of a flow frequency curve, with drought stages shown. Notice that the scale on the top of the graph is not linear, and ranges from 2 to 98 percent. Statisticians use this type of graph to draw theoretical distributions from raw data. For a true random distribution of data following Gaussian characteristics, the data

[7] *New York State Drought Preparedness Plan.*

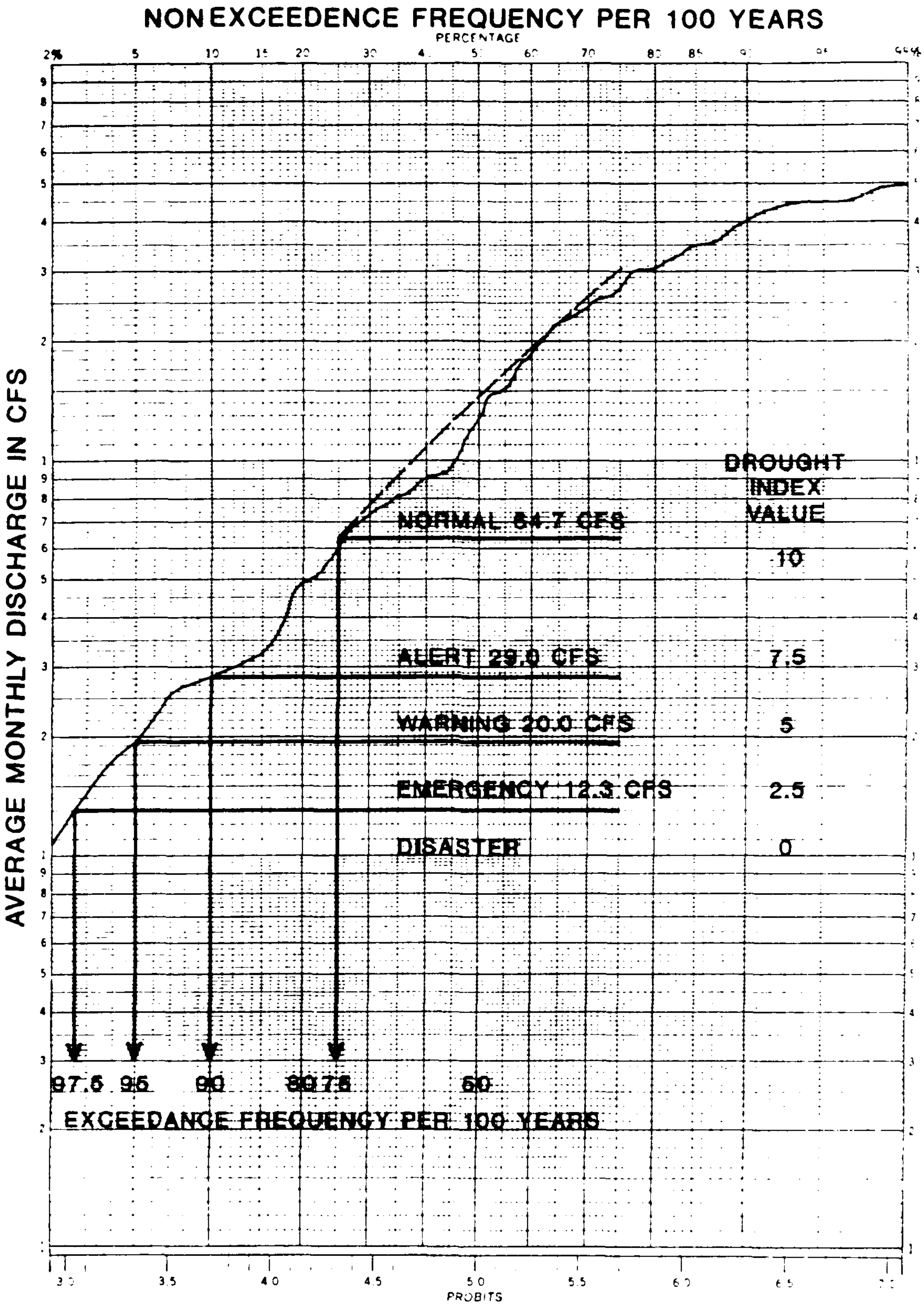


Figure 9. Example of flow frequency curves as a drought forecasting technique.

will plot as a straight line. The data shown in this example approach a straight line, except in the high-flow region. This type of analysis should only be applied to natural streams without flow control structures such as dams. This is a very important point, because a dam used in a water management system would control the flow and make the frequency distribution nonrandom. In cases where there are flow control structures, drought forecasting should be estimated from precipitation or reservoir/lake level as described on p 21.

Groundwater Levels

Groundwater levels are influenced by infiltration of surface water and precipitation in recharge areas and are often interconnected with streams and lakes. Shallow groundwater levels are affected in the early stages of drought, but deeper levels may not be affected for some time. Groundwater levels are not as sensitive to temporary drought weather aberrations due to the time required for infiltration to occur. Lag-time is normally expected between the rainfall and its effect on recharging the groundwater table. This lag time is the effect of time required for infiltration to occur. However, in systems relying on a combination of groundwater and surface water, increased reliance on groundwater during drought may cause the water level to drop more rapidly than in areas whose only source is groundwater. Recovery of groundwater levels after a lengthy drought is usually a clear indication that a drought is over. Observation wells are needed to measure groundwater levels. Based on long-term records, the maximum, minimum, and average groundwater levels can be compared with current levels to determine drought status. Army installations should monitor static groundwater levels in production and/or observation wells so that during drought, long-term trends can be established.

Figure 10 shows how groundwater levels are related to recharge areas and also shows the difference between confined and unconfined aquifers. The impervious stratum could be a clay layer, in which groundwater flow is very slow, moving less than 1 in. (25.4 mm) per year in some cases. The confining stratum could be bedrock or another layer of impervious material.

Shallow private wells in unconsolidated material are often located in areas where groundwater flow is relatively rapid, and require only a limited saturation zone above the water intake point. The saturation zone is the area that is completely saturated with flowing water. The top of this zone in unconfined aquifers is the level at which water would freely stand in an unpumped well. This level is also called the water table. Wells in shallow, unconsolidated material are the first to suffer in droughts. Thus, they are indicative of the drought alert stage.

Wells drilled a few hundred feet and having a "saturated" zone of 100 ft (30 m) or more experience delayed effects of lowering water levels. Unlike surface water, groundwater moves very slowly. The deeper the well and the greater the thickness of the saturation zone, the less effect drought will have on a well. The saturation zone is, in effect, a natural storage reservoir, and declining water levels indicate depletion of this reservoir. Deeper wells experiencing declining water levels indicate the drought warning stage.

Valley-floor wells are situated at the "base level" of the geologic formation; they drain the local or regional system and are underlain by impervious bedrock. These wells have a much greater delay from water deficiencies. Generally, the stream has to "dry up" for the valley-floor aquifer to have a lowered water level. Thus, valley-floor water levels lower than those of record probably indicate drought emergency or disaster.

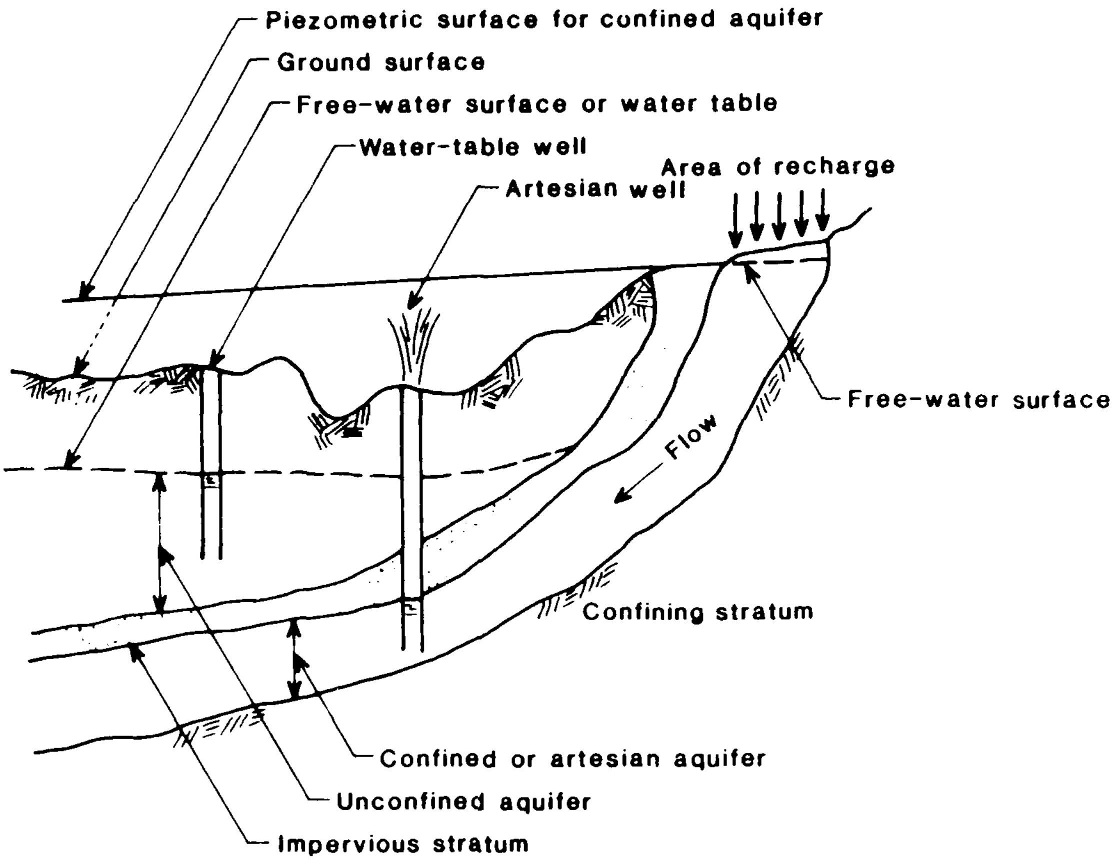


Figure 10. Groundwater and well characteristics.

Man's intervention into the environment can also greatly affect water levels. In urban areas with the shallow, unconfined aquifers, the development of land for housing can seriously affect recharge. In land development, stormwater and sanitary sewers can intercept water percolating to the groundwater table and divert it to surface streams. Also, many provisions are made for groundwater runoff, which diminishes the size of a recharge area. Declining water levels in deeper wells can result from over-pumping. This is called "mining" the water, because water is being removed from the ground faster than it can be replenished. These factors must be kept in mind when comparing current to historic water levels. The first question to be answered is whether recent manmade changes are responsible or whether lowered water levels really signify a drought.

Summary of Forecasting Techniques

All forecasting techniques are related to input of precipitation, which cannot be controlled. Comparing current precipitation to historic levels is the base method for determining the existence and seriousness of a drought. Storage systems, both natural (lakes, groundwater) and manmade (reservoirs), can be monitored to determine the drought stage. Current streamflow can also be compared to historic levels to indicate the degree of drought. In all cases, historical comparisons must consider man's intervention, including water management systems and other structures (e.g., stormwater sewers) that affect the natural flow of water. Figure 11 shows how all the drought

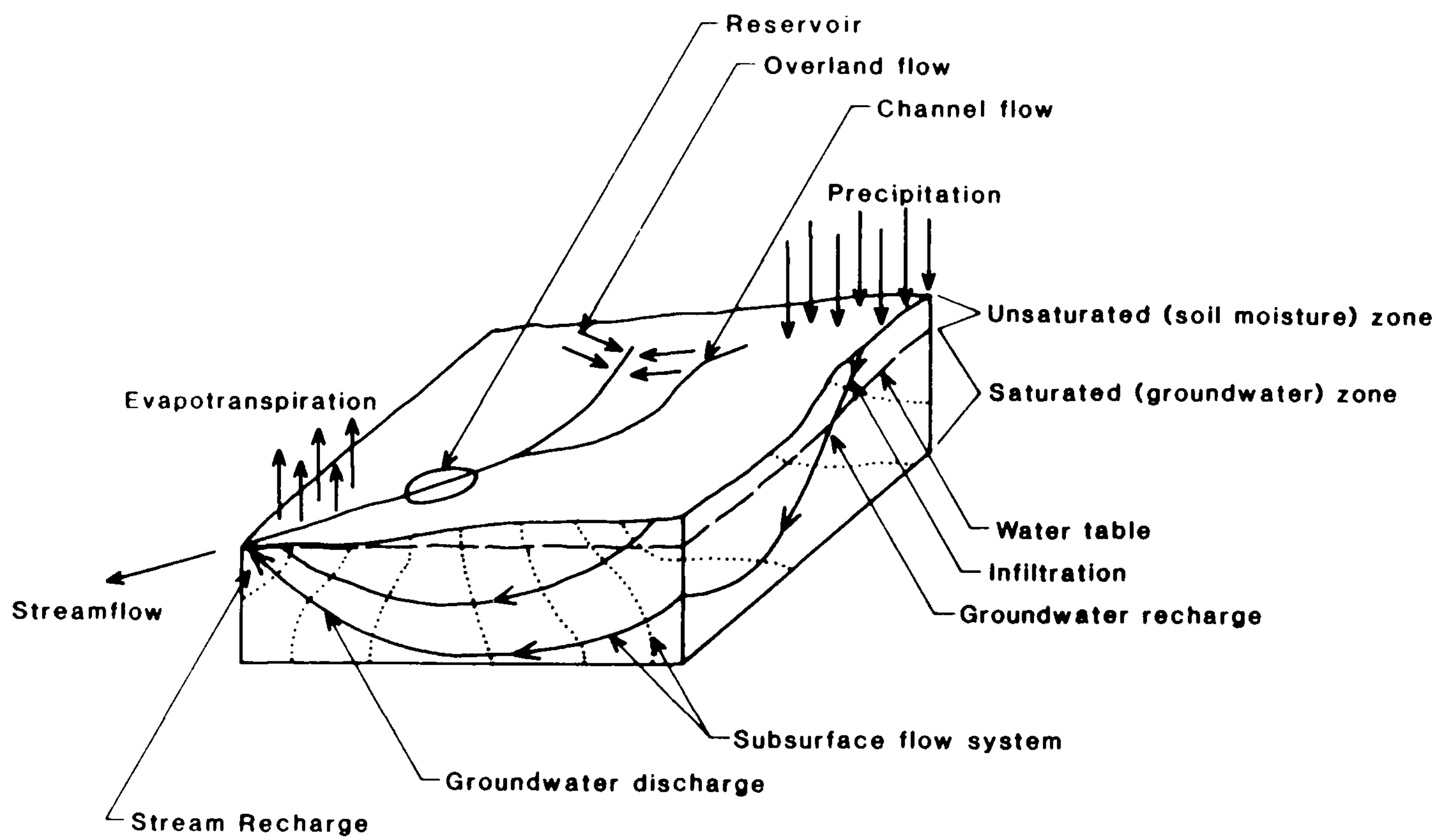


Figure 11. Schematic of the hydrologic cycle.

indicators are related in the hydrologic cycle. Aberrations in the hydrologic cycle are the underlying cause of drought and measures of the levels of these aberrations indicate the stage of the drought.

As shown by the following example, caution should be exercised in using geophysical forecasts. A drought forecast for the Yakima River made in January 1977 by the U.S. Bureau of Reclamation resulted in a $20 million lawsuit against the Government. The plaintiffs (local farmers) incurred a documented cost of $20 million for adjustments such as selling land, drilling wells, and changing crops in response to a forecast that lowered their annual water allocation to 7 percent of normal; however, errors were subsequently discovered in the forecast calculations. Farmers actually received 70 percent of their normal water allocation, resulting in a court decision that the earlier expensive adjustments were unnecessary.[8]

[8]Dracup, 1986.

4 CONSERVATION STRATEGIES

Water conservation, which is a direct function of the drought severity and the drought stage status, must be reviewed periodically to estimate conservation efficiency during the drought stage. Several water users and applications will be reviewed in this section, and the impact of pricing options will be considered.

Water conservation has been the subject of two previous USA-CERL reports[9] which documented an investigation of water conservation techniques that would not affect normal Army operations. The concepts presented in the current study are intended for drought conditions whose effects on normal operations may be unavoidable.

Residential Conservation

Metering

One of the major factors affecting residential water consumption is whether the distribution system is metered. Metering has a direct impact on lawn-sprinkling and peak demands,[10] as shown in Table 1, which compares water use in metered and flat-rate areas.

Table 1

Water Use in Metered and Flat-Rate Areas (October 1963 to September 1965)

	(gpd/dwelling unit)	
	Metered Areas	**Flat-Rate Areas**
Annual Average		
Leakage and Waste	25	36
Household	247	236
Sprinkling	186	420
Total	458	692
Maximum Day	979	2354
Peak Hour	2481	5170

[9]R. J. Scholze, L. J. Benson, M. A. Kamiya, M. J. Staub, and J. T. Bandy, *Water Conservation Methods for U.S. Army Installations: Volume I, Residential Usage Management*, Technical Report N-146/ADA128550 (U.S. Army Construction Engineering Research Laboratory [USA-CERL], 1983); R. J. Scholze, L. J. Benson, M. A. Kamiya, M. J. Staub, and J. T. Bandy, *Water Conservation Methods for U.S. Army Installations: Volume II, Irrigation Management*, Technical Report N-146/ADA128516 (USA-CERL, 1983).

[10]C. S. Russel, D. G. Arey, and R. W. Kates, *Drought and Water Supply* (John Hopkins Press, 1970).

The Army has not installed meters because their use is unnecessary if individuals do not pay for their own water. However, meter installation is recommended for two reasons: (1) meter readings will show when undetected leaks dramatically increase water outlay and (2) during drought emergency conditions, meters can be used to enforce rationing programs. Also, the effects of water conservation cannot be determined on an individual basis (i.e., how much each building is reducing use). This can be extremely important, as explained in the section on rationing below.

Meters are mechanical devices that require extra costs for maintenance. Domestic meters should not be left in service more than 8 to 10 years before they are rebuilt. With corrosive waters or water containing sand and grit, 20 percent of meters will not register flows below 0.7 gpm (0.045 L/s). For maximum efficiency of registration, it is recommended that the meter be preceded by a straight pipe. The length of this pipe should be eight to 10 times its diameter.[11]

Pressure Regulation

A pressure reduction throughout the water supply distribution system is a first step for conserving water during drought. For example, reducing the water pressure 25 percent during the 1977 drought in England decreased water use in the metropolitan area by about 10 percent compared to the normal average.[12] At present, the California Uniform Plumbing Code requires reduction of any pressure greater than 80 psi (550 kPa).[13] Pressure regulation reduces both leakage and the need for maintenance of faucets and toilet valves, thus providing an equitable, reliable year-round water-saving feature. A study by Washington Suburban Sanitary Commission reported overall conservation of 16 to 24 percent by reducing pressures to an average of 50 psi from normal operating pressures of 70 to 120 psi.[14] Pressure is regulated by installing small orifices in a pipe where it enters a building. This procedure does not reduce fire protection capabilities, since the water pressure in the mains is not changed. It also allows for selection of individual buildings for pressure reduction, thus avoiding facilities that cannot function with a pressure reduction.

Rationing

Rationing can be used only in metered systems, because without meters, there is no control method to measure use and enforce compliance. When the possibility of cutting down or cutting off supplies to certain areas is being considered, it is important to look at the type of building structure. For example, cutoff is acceptable in single-family homes or condominium areas, but is impractical in multistory apartment housing or buildings that run an unusually high risk of fires.

---

[11] William D. Hudson, "Increasing Water System Efficiency Through Control of Unaccounted for Water," *Water Conservation Strategies—An AWWA Management Resource Book* (American Water Works Association [AWWA], 1980).

[12] Anne M. Blackburn, "Dealing with Drought, Management Strategies," *Water Conservation Strategies—An AWWA Management Resource Book* (AWWA, 1980).

[13] Brian G. Stone, "Suppression of Water Use by Physical Methods," *Water Conservation Strategies—An AWWA Management Resource Book* (AWWA, 1980).

[14] Stone.

A severe measure was planned but not implemented during the 1977 summer drought in England: 17-hour cutoffs of the water supply.[15] However, such cutoff rationing has been used in the Sinai by U.S. Army peacekeeping forces.

Following are the most commonly used rationing programs:[16]

1. Flat percent reduction where all users reduce consumption by a certain percentage. This procedure has the major advantage of being easy to enforce. It is more effective for commercial users than residential users, since industries can often reduce consumption by 10 percent without serious problems; however, the establishment of a review committee for variances is recommended.

2. A variable percent reduction in which each user is assessed a percentage reduction according to a base year's use.

3. Maximum allowance use specifying the amount of use per time period (day) per user. In this program, meters should be read monthly.

It should be noted that one problem with percentage reduction methods is that they essentially "reward" those who have not been conserving in the past and penalizes those who have been careful. It is difficult to administer if based on per capita use.

An underlying factor in all the above programs is "fairness."[17] Fairness is improved mainly by basing rationing allotments on numbers of people served, rather than on past use, size of lawn, or ability to pay. However, from a practical standpoint, there is a trade-off between fairness, efficiency, ease of enforcement, and administration.

During the 1977 summer drought in England,[18] some rationing programs allowed as little water as 50 gpd/person (190 L/person/day). On the other hand, during a water rationing program in Okinawa, Japan, it was estimated that for households, water needs were as little as 8 to 12 gpd/person (30 to 45 L/person/day) of nonpotable water use in addition to 1 to 2 gpd/person (4 to 8 L/person/day) of potable water. For businesses and offices, 2 to 4 gpd/person (8-15 L/person/day) of nonpotable water were required.[19]

During a water-rationing period, there is the possibility of waterborne disease outbreaks. This is because when the water system is interrupted for more than 2 hours, the empty lines become vulnerable to infiltration (i.e., potentially contaminated water entering a pipe intended for potable water only). In such cases, nonpotable water will flow out of the taps until the system has operated normally for more than 24 hours. However, harmful effects can be offset by adding household bleach to the water or boiling it for 5 minutes.

---

[15] Blackburn.

[16] *Before the Well Runs Dry, Volume II—A Handbook on Drought Management* (AWWA, 1984).

[17] W. H. Bruvold, "Residential Water Conservation: Policy Lessons From the California Drought," *Public Affairs Rept., Institute of Government Studies Bulletin*, Vol 19, No. 6 (University of California, Berkeley, CA, December 1978).

[18] Blackburn.

[19] Sidney B. Gerald II, "Water Rationing on Okinawa," *Water Conservation Strategies—An AWWA Management Resource Book* (AWWA, 1980).

Several rationing programs have been analyzed in the literature. During the California Drought on the East Bay, all residential customers were allotted 280 gpd (1.06 m^3/day); an additional 60 gpd (0.23 m^3/day) was added for each person in excess of three.[20] The overall goal for this program was a 25 percent reduction. The following cutbacks were also required from different users based on a percentage reduction from the previous year's consumption:

Industrial cutback	10 percent
Public agencies	25 percent
Apartment complexes	30 percent
Nonresidential irrigation	50 percent

This program was later modified to reach an overall goal of 35 percent reduction for the entire year. The household allotments were reduced to 225 gpd (0.85 m^3/day) plus an allowance of 35 gal (0.13 m^3) per person in excess of three. The reduction for other categories was lowered further on the basis of the previous year's consumption as follows:

Industrial	20 percent
Commercial and public agencies	30 percent
Multiple dwellings	35 percent
Nonresidential irrigation	60 percent

Another interesting rationing technique was used successfully in Denver, CO.[21] The water district issued a watering calendar for sprinklers and lawn irrigation based on street address. Three symbols were chosen: square, circle, and diamond. Houses would irrigate on alternate days based on their assigned symbol and the calendar. The district also tried to control expansion of new construction by issuing only a limited number of new connections equivalent to fifty-two hundred 3/4-in. (19-mm) taps yearly for the following 4 years. The result of both conservation measures was a 21 percent reduction in water consumption. Water use dropped to 29.8 billion gal/year (114 million m^3/year) from an average of 37.8 billion gal/year (143 million m^3/year) based on the previous five-year average.

Flow-Regulating Devices

Installing water-saving fixtures is a popular technique for water conservation. A great deal of literature describes the available kits and analyzes their performance and public acceptance. A few examples are given below. Many are available from local plumbing supply houses. Appendix A provides a list of large-order suppliers.

Toilet dams (passive action) have been compared to behavior modification (active action) in terms of water savings. The toilet dam installation can save an average of 15 percent[22] whereas flushing the toilet less frequently (without a toilet dam) can save 50 to 75 percent of toilet water use.

---

[20] John S. Harnett, "Effects of the California Drought on the East Bay Municipal Utility District," *Water Conservation Strategies—An AWWA Management Resource Book* (AWWA, 1980).

[21] W. H. Miller, "Mandatory Water Conservation and Tap Allocations in Denver, Colorado," *Water Conservation Strategies—An AWWA Management Resource Book* (AWWA, 1980).

[22] I. M. Rice, L. G. Shaw, "Water Conservation - A Practical Approach," *Water Conservation Strategies - An AWWA Management Resource Book* (AWWA, 1980).

During the 1977 drought at Oxnard, CA,[23] water conservation kits were distributed at no charge to a single large geographic area. The kits included a toilet dam and shower flow restrictor. Data on public acceptance were gathered 1 month after the program had begun by interviewing the water users. Results showed that residences having higher water use, whose occupants had professional or craftsman backgrounds tended to install the kits at a slightly higher rate than the average population. The age and number of household residents also affected the rate of installation, with younger families (<25), those in the 55 to 64 age group, and households having five or more residents using the kits more than the average. Eighty-eight percent of those who installed the kits felt they were operating satisfactorily. Toilet dams tended to operate better in newer units, and complaints were generally stronger from residents in older dwellings.

In distribution systems, water use can usually be reduced by inserting flow restrictors on services at the meter. Such restrictors can be sized to adjust for service length, system pressure, and site elevation, ensuring that all users in a defined service classification have the same flow capacity at the meter.

Device Evaluation and Selection

Each facility must develop its own criteria for choosing the most effective water conservation device or equipment. Major elements to be considered should include cost, budget, type of device, type of existing system, conservation goals, and resident's preferences. Also, each building may have unique flow-rate and water demand characteristics that will require a trial-and-error approach to see which devices or combinations of devices and fixtures are satisfactory.

Table 2 lists the most common fixtures currently in use and provides brief comments on their costs and functions. USA-CERL Technical Report N-146 provides a complete description and list of manufacturers for these fixtures.

Table 3 summarizes the estimated water use reductions achieved by using these different water-saving devices.

A study was conducted in Pennsylvania State University undergraduate dormitories to determine the amount of water saved by installing shower flow controls.[24] Showers under study were equipped with an adjustable stream showerhead having a flow control and a pressure-balanced mixing valve to automatically temper hot water to a preselected water temperature (107°F [41°C]). Cold-water uses were compared between controlled and uncontrolled areas for each measurement period. The devices were alternately installed and removed over 4-week periods. Control studies were conducted when no flow control devices were in place. Thus, alternating measurement periods compared controlled/uncontrolled consumption for the same showering area. A separate dormitory was also used as a control.

---

[23] W. D. Morgan, and P. Pelosi, "The Effects of Water Conservation Kits on Water Use," *Water Conservation Strategies—An AWWA Management Resource Book* (AWWA, 1980).

[24] William E. Sharpe, "Water and Energy Conservation with Bathing Shower Flow Controls," *Water Conservation Strategies--An AWWA Management Resource Book* (AWWA, 1980).

Table 2

Common Water Conservation Fixtures

Fixture	Capital Cost	Function	Comments
Toilet Tank	$0.90-4.00	Reducing water use by displacing water with plastic bottles, bags, or dams.	Suitable for large toilet tanks. Retrofit to conventional fixture.
Faucet Aerator	$1.00-5.00	Reducing water use and splashing by adding air to water. Laminar flow units give more efficient rinsing.	Well accepted by consumers.
Shower flow Restrictors	$0.75-25.00	Restrictor: Allowing specific flow at specific pressure through a fixed opening.	External or internal retrofit to conventional fixture.
		Regulator: Compensating for different pressures and closing under increased pressure.	External or internal retrofit to conventional fixtures. Saving more water and adding flexibility under varying conditions.
Shower Pressure Balancing Mixing Valves	$45.00	Maintaining selected water temperature within a range of pressure.	Avoiding thermal shock and water waste.
Automatic Clothes Washer	N/A	Providing variable water levels and a suds-saving cycle that reuses washwater. Saving hot water and detergent.	Not generally used.
Automatic Dishwasher	$175.00 350.00	New models allow residents to vary the amount of water used, depending on the size of the load.	Widely used.

Table 2 (Cont'd)

Fixture	Capital Cost	Function	Comments
Hot Water Pipe Insulation	$0.50/ft	Avoiding water wastage caused by waiting for hot water flow. Saving energy and heated water.	Saves up to 8 gpd/person
Industrial Laundry Recycle	$30,000	Mechanically and chemically treating all washwater and rinse-water. Up to 80 percent reduction in water use.	Well accepted, 30 units installed. (For more information, call the USA-CERL Point of Contact: Rik Scholze, FTS 958-7743, (217) 373-6743).

Table 3

Summary of Estimated Water Reductions in Households Using Water-Saving Devices

(From Brian G. Stone, "Suppression of Water Use by Physical Methods," *Water Conservation Strategies—An AWWA Management Resource Book* [AWWA, 1980].)

Water Use Reduction Device	L/day	gpd	Percent
Toilet Improvements	28-66	7.5-17.5	12-27
Faucet Aerators	0-2	0-0.5	0-1
Flow Limit Valves, All Fittings	0-2	0-0.5	0-1
Shower Flow Limiting	0-28	0-7.5	0-12
Pressure-Reducing Valves	0-61	0-16	0-20
Metering	0	0	0
Septic Tanks	133	35	15
Improved Clothes Washers	0-30	0-8	0-5
Improved Dishwashers	0-23	0-6	0-4
Hot Water Insulation	0-23	0-6	1-4
Total	285	70	Range 13-52

Hot-water use was estimated by weighting flow rates, by temperature, for hot- and mixed water flow rates. Estimated hot-water quantities were used to estimate the gross dollar savings accrued from these devices. The study results indicated that 40 to 60 percent reductions were achieved by decreasing shower flow rates from 5.5 gpm (20.8 L/min) (in the control dormitory, and in all dormitories when no flow restrictors were used) to 2 to 2.5 gpm (7.6 to 9.5 L/min) (in dormitories with flow restrictors).

On Army installations, the typical use for residential-type bathing was estimated at 21 gpd/person.[25] Based on the 40 to 60 percent reduction in water use for showers, the savings in water and energy for heating can offset the cost of shower flow controls in 28 days.[26] If the actual flow reduction were as reported in Table 3, the payback period would be 6 months to 1 year.

While some communities considered installing these devices at no charge to water users, others like the city of Gloucester, MA, studied a plan to provide rebates on user charges to residents with water-saving devices.[27] Other communities in California installed flow restrictors in meters of domestic customers who persisted in using more than 2500 cu ft/month (71 m^3/month) above their allotment during drought seasons. The same procedure was considered for nondomestic users who exceeded their allotment by 50 percent or more.[28]

Under drought emergency and drought disaster conditions, it may be necessary to terminate use of flush toilet facilities or to terminate water service to a building. Portable chemical toilets that are typically used at remote sites or temporary building sites may be used during a drought at buildings with limited use, thus allowing water service to be restricted or eliminated. Portable chemical toilets are available in limited supplies at most Army installations, and additional chemical toilets may be purchased or leased through commercial companies. These companies can be located through the local telephone yellow pages, under the heading of TOILETS-PORTABLE-DEALERS. Costs for rental depend on period of contract, local demand, and transportation costs.

Unaccounted Water Losses

Water losses are unavoidable in water distribution systems, because the systems are always under pressure, and no system is entirely leakproof. USA-CERL Technical Report N-86/05[29] discusses the comparison of water produced and water consumed. Several examples depict the usefulness of reducing water loss and the level of acceptable water loss. The level of acceptable loss is influenced strongly by the cost of water, and there is no hard rule for acceptable loss. One rule of thumb used often in the water industry is an acceptable loss of 15 percent. Thus, in a metered system, the sum of all metered consumption should be 85 percent or more of the water pumped into the system. If the

---

[25]Scholze, Benson, Kamiya, Staub, and Bandy, *Water Conservation Methods for U.S. Army Installations: Volume I, Residential Usage Management.*

[26]Sharpe.

[27]L. A. Edmonds, and S. L. Bishop, "Planning for Droughts," *Consulting Engineer*, Vol 59, No. 3 (September 1982), pp 90-94.

[28]Harnett.

[29]S. W. Maloney, R. J. Scholze and J. T. Bandy, *Preventing Water Loss in Water Distribution Systems: Money-Saving Leak Detection Programs*, Technical Report N-86/05/ADA167556 (USA-CERL, 1986).

metered ratio is less than 85 percent, intensive leak detection is usually justified. During drought, leak detection programs can often be justified at ratios greater than 85 percent.

Following are the major causes of water distribution system losses and some recommendations for solutions:[30]

1. Use from hydrants, sewer flushing, and street flushing: allow an average of 1 percent of the total annual use (AWWA).

2. Unavoidable leakage from valves and joints: allow 2500 to 3000 gpd/mile (5.9 to 7.1 m^3/kilometer) for old lines and 1500 to 2500 gpd/mile (3.5 to 5.9 m^3/kilometer) for newly constructed lines.

3. Underground leakage: monitor the night rate flows from previous records.

Many leaks occur at valves connecting a building to the water distribution system. These types of leaks can be identified and corrected quickly. Leaks in distribution system mains are more difficult to locate because they are not visible. In sandy soils, or where there is a nearby outlet for the leaking water such as a stormwater sewer, very large leaks can occur without affecting the appearance of the surface.

Industrial Users

The following checklist was prepared by the British Confederation of Industry to help reduce water use during the 1977 summer drought.[31] This list introduces some features that can be adopted by U.S. Army industrial facilities.

1. Appoint a suitable staff member to be responsible for investigating water use and reducing consumption.

2. Draw the attention of all members of the workforce to the need to save water and the effort the company should make to this end. Emphasize also the need for savings at home.

3. Fit water meters in key areas of expected high water use so that actual flows can be monitored.

4. Read water meters at set times and monitor consumption.

5. Investigate any increases in consumption.

6. Identify machines through which water continues to flow, even when it is not in operation; install automatic cutoff or ensure that operator turns the supply off whenever the machine is not in use.

7. Identify all taps within the plant and shut off any not readily required.

8. Seek out all leaks; reseal joints, replace washers, refurbish or replace valves, and replace packing on leaking glands.

---

[30] Hudson.
[31] Blackburn.

9. Inspect the water storage and distribution system at least once per day, and attend to leaks immediately.

10. Check overflow discharge points regularly, and take immediate action to stop flow.

11. Identify every item of plant or machinery that uses water, and establish *minimum* water requirements for each which should not be exceeded without good reason.

12. Throttle supplies where possible.

13. Discontinue drinking fountains, and supply disposable cups and drinking water taps.

14. Identify all hoses; ensure that the smallest diameter necessary is used and that each is fitted with a spring-loaded automatic shutoff.

15. Collect uncontaminated cooling water and reuse for cooling, as process water, for toilet flushing, or plant washing equipment, if possible.

16. Remove as much solid residue as possible when cleaning the plant. Wash in a fixed quantity of water; never wash under running water.

17. Reduce boiler use if possible; save and reuse "blowdown" water.

18. Limit vehicle washing to essential health, safety, and hygiene requirements, and use a bucket, not a hose. (Note: this does not apply to vehicle washracks which practice recycle. These installations already maximize water conservation.)

19. Keep firefighting water and sprinkler tests to a minimum, but consistent with safety.

20. Check cooling systems in offices; switch them off when not in use.

21. Use countercurrent flow rinsing.

22. Reuse rinsewater.

23. Discontinue shower facilities where possible; limit shower times.

24. Fit hand basin taps with spray nozzles; if possible, supply only warm water, and discontinue cold taps.

Community Activities Use

The following bans and restrictions can be imposed, depending on the drought stage. They can be implemented in either metered or nonmetered systems.

1. Ban nonessential residential use. Measures should be enforced on activities such as landscape irrigation, car washing, pool filling, and hosing of paved surfaces and buildings.

2. Restrict certain commercial uses such as automatic flushing systems in public restrooms, vehicle washing for other than hygiene and safety, and building exterior cleaning. Require recycling of cooling water for large air-conditioning units. These actions are to be implemented according to the drought stage.

3. Discontinue certain municipal uses such as street cleaning, water main flushing, hydrant flushing, public fountains, and irrigation of parks and roadside landscapes. Actual savings from these measures might not be significant in terms of water quantity, but they convey the seriousness of conditions and provide a leadership example for installation personnel.

Irrigation

During drought, it may appear that all irrigation should be discontinued. However, some types of vegetation on an installation require more time and expense to replace than others. In particular, older trees and vines are more important to maintain than grasses. However, there will be limited opportunities to make specific contingency plans for redistribution of surface water for this purpose. Various actions aimed at stretching the available surface and groundwater supplies are summarized as follows:[32]

1. Plant only short-growing-season crop varieties consistent with economic conditions and the local ecosystem.

2. Prepare land so that it will prevent winter rainfall runoff, which increases groundwater recharge.

3. Implement irrigation management services to maximize existing water supplies. Examples include using more sprinklers and drip irrigation, lining ditches, matching crops with soil conditions to reduce percolation, reducing acres planted to equal full irrigation supplies, and intensifying weed control programs.

4. Forego application of extra water to leach salts from the land until more water is available.

5. Discourage expansion of irrigated lands in areas of severe groundwater overdraft.

6. Increase public awareness announcements on ways to save water by reducing or curtailing irrigation demands.

7. Examine the effect of relaxing standards for using grey water on selected areas.

8. Establish water need priorities, considering:

   a. Type of crop to be irrigated

   b. Absence of reasonable alternative source.

[32] *Alternative Drought Strategies for 1978* (State of California Governor's Drought Emergency Task Force, January 1978).

One good point about drought is that it may be an impetus for accelerating groundwater well-drilling programs. Use of both surface and groundwater supplies should be a long-term planning goal. Development of a drought contingency plan showing insufficient water supply development can also help get funds. One of the main advantages of a planning process is getting structures in place before the need becomes critical.

Other Conservation Strategies

The following discussion considers the effect of pricing as a conservation method. These proposals have been adapted from the public and private sectors, and may be of some use to Army installations. Pricing, which can only be used in metered systems, has shown more success with commercial and industrial sectors.

The most common three pricing strategies that can be adopted in an emergency are described below:

1. Seasonal Rate Schedules: Charge a higher price for use during peak months. This measure is generally more suitable for residential users with a nonuniform consumption pattern. On Army installations, this could be done by charging a high price during peak seasons for use over a certain base level; below the base level, there would be no charge.

This strategy would be of limited use on an Army installation, because personnel do not currently pay for water service. However, commercial tenants on an installation are charged, and thus may be affected by pricing strategies and penalties for excess use.

2. Excess Use Charge: Increase the price dramatically per unit above a specific amount of use per billing period (an increasing block rate structure). This measure can be difficult to apply for industrial users with variable plant designs and product requirements, since no uniform amount of water use can be assigned fairly for their purposes. However, on Army installations, this strategy could be implemented as follows:

Up to X gallons	Free
All Use $>X$ but $<Y$ gal	$1.5/1000 gal
All Use $>Y$ but $<Z$ gal	$3.0/1000 gal

The concept here is that all personnel have a right to use a normal amount of water, which would be free. Personnel who waste water would be charged at a high rate. Furthermore, the more water wasted, the greater the cost per 1000 gal (3.8 m^3) wasted.

3. Penalty Charges: Assess a flat fee for use above a certain amount. (This fee could increase if a user continues to exceed the set amount.) Here, the criteria for determining the fixed amount must be spelled out in advance. This would be essentially a single set fine for excess water use on an installation, with no charge for use below the set level.

The Army's policy of not charging installation personnel for water service makes direct transfer of these concepts from the public sector inappropriate. However, installation of meters would at least allow water use at each household to be estimated. Penalty charges could then be assessed to households using excessive amounts of water, and rewards, either monetary or symbolic, could be given to those using the least amount.

Summary of Conservation Strategies

The conservation strategies presented here combine hardware and water use modification. Most of the hardware falls in the area of flow restriction on existing water uses. Additional hardware that allows water reuse can also conse: e significant amounts of water. All hardware options are best put in place before a drought occurs.

Water use modification includes rationing and pricing strategies. These methods allow the user to allocate water use based on individual priorities. They can be particularly effective with commercial tenants whose water supplies are metered.

One overlooked benefit to conservation is the good public relations it generates with the surrounding community. Such relations are essential when negotiating with other water users for allocations during a drought.

5 SUPPLY AUGMENTATION

Increasing the available water supply to meet demands is the most desirable method of drought control. This approach involves establishing a water management system that can import water from outside the affected area, construct surface impoundments to save water from periods of high flow for use during low flow, or tap previously unused natural water storage systems. This section will begin with a discussion of "safe yield" from a number of raw water sources, list supply augmentation techniques, and then give a few examples from the public and private sectors of techniques used as drought responses.

Safe Yield

Safe yield is a critical factor when increasing withdrawal from water resources. The definition and calculation of safe yield vary, depending on the type of water resource (i.e., surface or groundwater). This concept applies to systems that have storage capacity, such as reservoirs and aquifers, but not to uncontrolled streams.

Reservoirs

The maximum possible yield equals the mean inflow minus evaporative and seepage losses. The safe, or firm, yield is the amount of water that can be withdrawn from storage in a specified interval of time (usually during a dry period or drought). If streamflow were constant, no reservoir would be needed. However, the larger the variation in streamflow, the larger are the reservoir requirements so that the water resource can be used to its fullest. The critical time interval can vary from 1 day for a small distribution reservoir to 1 year or more for a large storage reservoir that may rely on one rainy season or spring snowmelt runoff to supply its entire year's demand. Reservoir design normally allows for enough storage to meet some type of design drought conditions. In the Northeast,[33] common practice is to design for a drought of probability 0.05 (one drought in 20 years) and to add a reserve of 25 percent to the computed storage volume. Another practice is to use the period of lowest natural flow on record. In cases of rare droughts, a safeguard for yield would require the reduction of withdrawal rates through water conservation. For a general rule of thumb in the Northeast, a safe yield is 600,000 gpd (877 $m^3/d/km^2$) per square mile of drainage area.

Wells

Safe yield of a well is the amount of water that can be withdrawn annually from a groundwater basin without producing undesired results, such as permanent decline in the water table. A decline in the water table leads to increased pumping costs, and in coastal areas, can lead to salt-water intrusion. Safe yield is a function of hydrology, geology, and economics. There are three general cases for determining safe yield.

1. Limit determined by availability for recharge. This case often occurs in arid regions. Safe yield is the precipitation minus evapotranspiration, surface runoff, and subsurface discharge from the aquifer. Such aquifers may show little or no drawdown during wet periods, and wells will have a very wide radius of influence during a drought.

[33] *Before the Well Runs Dry, Volume II--A Handbook on Drought Management.*

2. Limit determined by transmissibility of the aquifer. This case occurs when the aquifer material does not allow water to flow easily. Transmissibility is the flow through a unit width of the aquifer at a unit gradient, and is expressed as gallons per day per foot of aquifer per foot of drawdown. Coarse-grained materials such as sand and glacial till allow water to move freely, whereas fine-grained materials such as clay and silt greatly retard water movement. Wells in such aquifers may experience very large drawdown locally without affecting the local water table substantially.

The method used by the State of Massachusetts[34] is an example of this type of safe yield limit. The formula multiplies transmissibility by available water by a safety factor of 0.75 to determine the safe yield of a large-diameter pumping well. The available water is the depth of the pumping well minus the length of screen minus the static water level minus a 5-ft (1.5-m) safety factor (i.e., a measure of aquifer thickness and available drawdown). Well designs tend to size pumps to run at the safe yields for 12 hours per day to meet average demand and 18 hours per day to meet maximum demands, such as those occurring during the summer.

3. Limit determined by potential for contamination. Wells form a gradient in the water table that draws the water toward them. This is superimposed on the natural gradient in which water flows from the aquifer recharge areas to the discharge areas. In areas of natural (e.g., brackish water) or manmade pollution, wells must not draw water at a rate that would cause contaminants to migrate toward the well. During drought, the slope of the natural gradient may decline, increasing the likelihood of pollutant migration.

AWWA Plan for Supply Augmentation

Supply expansion is time-consuming and cannot usually be undertaken as an emergency response. Surface impoundments constructed while a region is entering a drought may be of little use if no time is available for the impoundment to fill from a period of high flow. The American Water Works Association (AWWA) has an 11-point plan to augment supply during drought. This plan and a discussion of its applicability on an Army installation is given below.

1. Use surface supplies not normally used for raw water supply (e.g., recreation ponds, golf course ponds, etc.). Ponds used primarily for recreation may not be designed to deliver water to streams that feed into the normal raw water supply. It may be possible to divert water by pumping or hydraulically modifying the impounding structure to allow more water to pass. The latter could be done by installing or modifying outlet works. In extreme cases, Army field water treatment units could be installed at ponds or lakes, with the treated water pumped into trucks for redistribution.

2. Use reservoir water not usually available (i.e., dead storage). Dead storage is the volume of water remaining in the reservoir after the pool level falls below the lowest intake. Figure 12 shows various types of storage behind a dam. Although this type of storage is not available to normal water intakes, pumps mounted on rafts can be used to withdraw this water and pump it into the discharge stream or water treatment plant.

---

[34] *Before the Well Runs Dry, Volume II--A Handbook on Drought Management.*

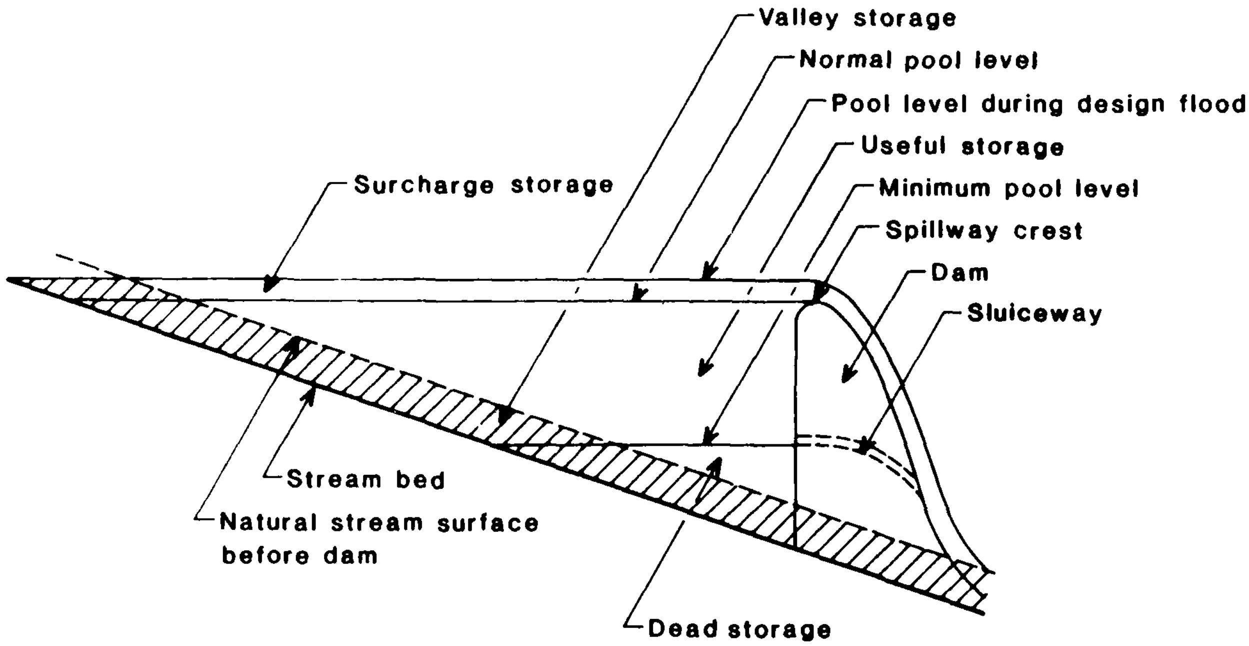


Figure 12. Reservoir storage zones.

3. Develop new wells or drill deeper wells. The section on groundwater (pp 24-25) lists several types of wells classified by depth, ranging from shallow wells to valley floor wells, which exist just above bedrock. Several aquifers may be separated by impervious strata having water. In either case, this method takes advantage of the aquifer's natural storage quality. Drilling new wells into an aquifer that has already been tapped by existing wells may work when the well yield is limited by aquifer materials of low hydraulic conductivity; if this is the case, the well's radius of influence (the area in which well pumping causes the water table to be depressed) is not very great. In areas of high hydraulic conductivity, the water table may be drawn down over great distances, and deeper wells would be required to push the water intake below the drawn-down water table or to tap new, deeper aquifers.

4. Reactivate abandoned wells. Wells are abandoned for many reasons. Older wells may be abandoned due to the discovery of better-quality water or because a water system has been converted to a surface supply. These wells may still have a limited capacity to supply water, even if deeper wells have been installed that are experiencing drawdown problems. This can occur if there is a confining stratum between the two aquifers. In essence, the upper aquifer still has storage capacity that can be used, although it would be limited by the absence of recharge during a drought.

During the initial development of a drought plan, Army installations should identify abandoned wells and determine why they were abandoned. If they were abandoned for reasons related to health quality, they can only be used under drought emergency conditions for nonpotable demands, such as fire fighting. If the quality can be brought up to potable standards, the well equipment should be tested when the alert stage is reached. Wells that are at nearly usable conditions should be repaired for use when the drought warning stage is reached. These wells can be activated during warning or emergency conditions, depending on the effectiveness of other drought mitigation measures.

5. Use emergency connections with other water systems. The use of interconnections between water systems is good engineering practice when the installation is not so isolated that no other systems are available. For installations that provide for all their own water needs, the interconnection is usually provided only for emergencies and may be closed most of the time. Installation personnel should familiarize themselves with the location of interconnections as well as the potential effects of opening an interconnection. It is essential to know at what system head the connected systems are operating. If a water-short installation operates at a higher head (i.e., water pressure), then opening the connection may only compound the problem by draining elevated storage to the point that both systems are equal.

Although droughts usually occur over a wide area, adjacent systems may be affected to different levels if the water supply of one system has a better water management system than the other. Army installations should determine the supply capability of the connected systems and share this information with water authorities of the other systems. This allows any system with an emergency connection to know the capabilities of its surrounding water systems and to know if there is excess capacity that can be used via an interconnection.

6. Negotiate and build new interconnections. This alternative has the same advantages as the one above, except that the interconnection must be constructed after the onset of drought. Army installation personnel should determine which water authorities in their area have excess capacity and build interconnections with them if a suitable deal can be negotiated.

7. Use water from another community's interconnection if it is not already being used. This situation would exist if all communities in direct connection with an Army installation were at or near their supply capabilities and were unable to provide water to an installation, but a water utility that was indirectly connected* to the installation had an excess capacity. This is a more complex situation, because the hydraulics of two systems come into play, and many conditions must be favorable to transferring the water. However, it may be a viable option during a drought.

8. Divert water from other uses such as power generation, recreation, downstream water users, or recharge. This alternative redistributes a region's water supplies, at least temporarily. All water uses within a given watershed are stressed during drought, but the distribution of water uses is usually decided during normal water flow conditions. Therefore, it is reasonable to argue that some water uses with a lower priority than consumption can be curtailed during drought. This type of redistribution will have to be negotiated with the other water users.

*In other words, the installation has connection with Utility A, and Utility A is connected to Utility B, but Utility B is not connected to the installation.

The legal aspects of diverting water are complex, and are complicated by the fact that the United States has two basic water rights doctrines. These doctrines, known as riparian rights and appropriation rights, are derived from ancient French and Roman common law, respectively. In developing a drought plan, these rights must be recognized and followed. However, due to the excessive length of court proceedings, it is better to determine during the planning stage how water can be reapportioned rather than wait until the crisis stage. Thus, the installation's legal personnel should be involved in the planning.

If power is available on the regional grid from other sources, water can be diverted from power generation. Alternative power sources, quantities available, and costs should be identified during the planning stage and verified during the "drought alert" stage. Recreational use can be curtailed when it involves releases from a reservoir that is also used either directly or to maintain minimum streamflow for a water supply. Downstream water users may be able to curtail irrigation and/or industrial uses, but may require some type of compensation, and this will often involve difficult negotiations. Diversions from recharge are also difficult to justify, because a diversion limits input into a system that is also relied upon as a water supply.

9. Seek emergency relaxation of requirements for flow release from dams. This alternative places the Army installation in the position of a downstream user. There is little difference between this and diversion of water from downstream users, except that this involves diversion of water from upstream users. Again, this requires negotiations that are best concluded prior to a drought crisis. It represents a situation of requesting relaxation of water flow requirements that apply under normal conditions, but not during a drought.

10. Build emergency dams. This alternative could be applied if a river intake at a surface water plant was approaching the stage of being "dried up." It could also be used where average streamflow was sufficient to meet average demand, but insufficient distribution storage (treated water) made the water treatment plant experience wide fluctuations in demand. An emergency dam could be used to provide enough storage (untreated water) to meet peak demands.

Emergency dams can also be used to divert water or keep it from mixing with salty, brackish, or heavily polluted waters. Water intakes on estuaries have the unique problem of being threatened by upstream migration of the "saltwater wedge." Saltwater is denser than freshwater, and therefore tends to lie underneath the freshwater at the bottom of an estuary. The freshwater is, in effect, continuously pushing the saltwater out to sea. When the flow of freshwater decreases, this saltwater wedge can migrate upstream, and may approach freshwater intakes at water treatment plants. Small underwater dams have been considered to retain the saltwater wedge.

Water harvesting is a concept that could incorporate emergency dams. The dams would retain whatever rainfall occurred for use as streamflow augmentation or groundwater recharge.

Emergency dams are to be viewed as temporary structures that will be removed when the drought has ended. A temporary dam that is not designed to control flood flows, if washed away, can actually aggravate flood damage. Therefore, caution should be used in applying this alternative.

11. Reactivate abandoned dams. As part of the drought contingency planning, abandoned dams can be identified and evaluated for reactivation. The first questions to ask are why the dam was abandoned, and what is required to reactivate it.

It is important to know whether a dam was deactivated because of structural unreliability at low flows. If this were true, it would not be advisable to reactivate it. However, a dam that was deactivated because of potential problems at high flows or because of a change in the water management system could be reactivated. The effects of reactivation on downstream use must be assessed during planning, and the dam should be inspected to determine if it could be reactivated (i.e., find out if gates are operational, the level of erosion around the dam, etc.).

Augmentation Techniques

Water Treatment for Temporary Supplies

Items 1, 3, 4, 8, 10, and 11 discussed in the previous section suggest the use of water whose quality may not be amenable to treatment with existing unit processes at the water treatment plant. Portions of the Army's field Table of Organization and Equipment (TOE) may be useful for bringing the water up to potable quality, storing it, and distributing it. The relevant units are described below.

ROWPU. The Reverse Osmosis Water Purification Unit is currently in the Army TOE or is being supplied. These units employ use the latest technology for removing salt and other contaminants from water and are currently available in three sizes: skid-mounted 150,000-gpd (568 m^3/d) models, 3000-gph (11.4 m^3/hr) units, and 600-gph (2.3 m^3/hr) units. They are all readily transportable.

TWDS. The Tactical Water Distribution System is a collapsible 6-in. (150-mm) line. It can be used to pump large quantities of water at rates up to 600 gpm (2.3 m^3/min). The hose is manufactured in 500-ft (150-m) sections and features quick connections.

SMFT. The Semi-Trailer Mounted Fabric Tank can store up to 4750 gal of water. Larger fabric containers are available in 20,000 (76 m^3)- and 50,000 (189 m^3)-gal sizes. Tank trucks, referred to as Water Buffaloes, are also available for water storage and distribution.

ERDLATOR. This unit contains the treatment processes used in conventional surface water treatment. Its advantage is that it is portable and can be moved to remote locations. It does not provide treatment for brackish or saltwaters.

Cloud Seeding

Cloud seeding is a precipitation augmentation technique that is always publicized during extended droughts. Although the method can be successful, several conditions must be met before precipitation occurs. This technique also requires an extensive water management system such that precipitation is intercepted on the surface and directed to recharge areas or reservoirs.

Moisture is always present in the air, even on cloudless days. Precipitation occurs after one of several mechanisms causes droplets to form and exceed the updraft pressure and buoyant effects of air masses. The initial step in any precipitation mechanism is the formation of droplets around condensation or freezing nuclei. These airborne particles range from 0.1 to 10 μm, and are products of combustion, nitrogen oxides, or salt particles. Although they are heavier than air, their small size allows them to stay aloft indefinitely; precipitation is the principal method by which they return to the surface.

The formation of droplets is insufficient to ensure precipitation. After formation, the droplets grow in diameter very slowly, and simple diffusion will cause the droplets to reach an average size of only 10 μm. Such small droplets can be supported by an updraft velocity of less than 0.2 in. (5 mm) per second. Once the droplet gains enough mass to fall from the cloud into unsaturated air, it begins to evaporate. However, as long as the fall is through the cloud (saturated), collisions with additional droplets allow the droplet to grow in size.

Cloud droplet formation occurs on condensation nuclei or freezing nuclei when the cloud's temperature decreases enough that the air is saturated with moisture. This can occur when air masses of two different temperatures collide along a front, or when the warm, moist air rises due to convective forces, or when the air mass is moving up a mountain side. The latter case is called orographic precipitation, and cloud seeding has been effective under these circumstances.

Cloud seeding involves introducing condensation nuclei into the cloud. Although this represents only the initial step in a precipitation event, it can have a catalytic effect that causes some droplets to form and drop; this increases turbulence in the cloud and causes other droplets to be lifted high enough to condense and grow to sufficient size to reach the ground as precipitation. This increase in turbulence in the cloud mass increases the cloud's height. The ability to increase the height of a cloud is referred to as seedability. If the seedability is less than 2600 feet (800 m), the seeded cloud may produce less precipitation than nonseeded areas; if it is greater than 10,000 feet (3000 m), appreciable increases in precipitation may occur. Less precipitation may occur if the cloud was already undergoing substantial turbulence and addition of more condensation nuclei only caused the number of droplets to increase to the point that fewer droplets could become large enough to fall to the surface. (Conversely, introducing far too many nuclei into clouds whose temperature is low enough to produce hail may mitigate hail damage by causing many small ice crystals rather than the larger, damaging ones.)

The most common substances used for cloud seeding are dry ice (solid carbon dioxide) and silver iodide. Success in seeding orographic clouds was reported in the Kings River Basin in California from 1955 to 1964, during which a 6 percent increase in streamflow was observed.[35] This technique may be considered on a basinwide basis, if enough water management structures are in place to capture the precipitation. In a drought planning exercise, installation personnel should determine if this technique has been applied in their watershed in the past, who was responsible, and what steps are necessary to begin the process.

Examples of Supply Augmentation

During the 1980-81 drought in the Northeast, the cities of Gloucester and Rockport, MA, used several schemes[36] to increase the supply resources. These towns are located on land that juts into the Atlantic Ocean and are highly dependent on rainfall storage in natural and manmade reservoirs. Downstream water use was not a problem, because water was flowing into the ocean; thus, no negotiations for allotment were required. Some of the measures taken are described below.

---

[35] Linsley, Kohler and Paulhus.
[36] Edmonds and Bishop, pp 90-94.

Diversions

A short-range plan called for diverting water from a stream and small pond just downstream from an existing water supply reservoir into that reservoir. An intermediate stage was planned for several diversions from streams and swamps, using a minimum number of new dikes to redirect flow to existing reservoirs.

Some of the diverted streams flowed only during the months of October through June, so they did not represent a continuous source of water. The existence of a water management system (the reservoirs) allowed this contribution to be worthwhile. The value of a resource when it is scarce, such as water during a drought, makes even small increases in supply worthwhile.

Watershed Management

This alternative called for increasing the effective drainage area by diverting water from other smaller watersheds. The watershed management program entailed proper disposal of wastes generated at nearby stables, control over the types of chemicals applied to the golf course, and fencing of critical pastureland near the streams.

These types of management options required cooperation from the landowners. The water utilities began using all water that could be collected, but land use in the area was not restricted. However, the periodic nature of drought in this area had sensitized the community to needs for extra effort during drought. In other locations, public education may be required before such cooperation could be obtained.

Storage and Drainage of Reservoirs

Ratios of storage per square mile of drainage area vary significantly in the Gloucester reservoirs; some are overdeveloped, and others are underdeveloped. An operating procedure that allows transfer of water between reservoirs through a system of pumping stations and transmission mains can significantly minimize the waste.

During the 1977 summer drought in England,[37] authorities used the following measures to increase supply:

1. Increase flexibility of the existing system by employing a "high flow skimming and interconnection scheme"; this was done by constructing pumping and piping systems to link reservoirs and thus decrease the system's vulnerability.

2. Minimize water loss to the estuary by increasing backpumping to stop the freshwater flow.

3. Pumping treated sewage effluent to an empty reservoir and saving it for later use.

---

[37]Blackburn.

Summary

Options for increasing supply should be determined prior to drought and implemented based on information such as the drought of record, record low flows, and record low water table. The cost of implementing new water management structures should be weighed against the cost of conservation practices. A major problem in implementing water projects prior to need is the strain on limited financial resources. However, there may not be time to implement water projects after a drought begins.

Water projects require relatively long lead time and will cost less if done under nonemergency conditions. If construction must occur after drought conditions are in effect, the experience of the California East Bay Municipal Utility District may help expedite legal, financial, design, and construction phases of emergency projects.[38] To overcome the lack of lead time and fabrication time, the following were recommended:

1. Use pumps from another project that can be delayed

2. Obtain major fittings from salvage yards.

Like all other aspects of drought, supply augmentation is highly specific to the nature of existing water management systems and depends on costs and yields that must be assessed individually for each option. The final decision is subject to the design drought severity and nature of available options.

[38]Harnett.

6 LONG-TERM DROUGHT EFFECTS

Water is such a basic commodity in the environment that its absence can produce far-reaching effects. Water is essential for transporting natural compounds and is widely used in waste disposal. Use of alternative water supplies during drought can also result in problems and costs not encountered under normal climatic conditions.

During a drought, pollutants and natural biological byproducts increase in concentration because there is less water to dilute them. Algal blooms brought on by water storage and continuous bright sunlight can lead to taste and odor problems in finished drinking water. Reduction in demand allows water to remain in water distribution systems for greater periods of time, so greater degradation can occur in the distribution systems.

Costs increase for water treatment and pumping. Water treatment requires more and different chemicals if sources whose quality is lower than normal are being used. Lower groundwater levels mean that the static head against the pump has increased. Thus, the water must be pumped to a greater height.

Saltwater intrusion can become a problem, both for groundwater supplies and for surface supplies located close to oceans or estuaries. In rivers and aquifers, the natural flow of freshwater toward the ocean continuously pushes the saltwater out to sea, and a relative equilibrium is established at the interface. When a drought interrupts this regular flow, saltwater can intrude on areas previously occupied by freshwater, which can include water supply wells and river intakes for water treatment plants.

Forest and rangeland can become extremely dry during droughts, dramatically increasing the risk and spread of fire. This can have serious effects on nonwater-consuming Army operations such as training. In the California drought of 1977,[39] two dry years had left forests in a virtually explosive condition. California has since developed a series of recommendations described below for dealing with problems posed by drought. These recommendations are aimed principally at nonmilitary operations. However, these recommendations can be modified and expanded to address military problems elsewhere, such as training in a forest.

Fire Prevention

Inspection of rural or outlying areas should be increased and rules adopted banning smoking except in designated areas. Special rules on smoking, with conscientious collection of cigarette butts should be adopted for training and range areas. Installations now practicing controlled burning on training areas and ranges should increase these efforts and other installations should begin using this technique. (Note: Controlled burning is used as a preventive technique to inhibit the spread of fires.)

Fire Suppression

Installations should increase aerial surveillance of training areas where possible and coordinate with nonmilitary agencies performing this function. Personnel should be

[39] *Alternative Drought Strategies for 1978.*

assigned to firefighting crews and provided with available equipment (jeeps, helicopters, earth-moving equipment). Water tankers should be provided at training areas and ranges for standby firefighting.

Sewage Treatment

Conservation and reduced infiltration/inflow during drought reduce the flow of water into a sewage treatment plant. This results in higher organic concentrations than normal and may make the plant noncompliant with effluent guidelines. Installations should consider what effect the increased concentration has on real loadings; although the concentration is above the limit, the actual organics loading to a stream may be well below the limit based on pounds per day, not concentration. This point should be kept in mind in any questions related to exceeding permit limitations.

Drought Recovery

Recovery from drought often brings additional problems that must be dealt with. The practice of removing timber damaged by insects and/or disease should be started or expanded. Additional funds and time for rehabilitating training areas should be provided. Army training exercises should be considered to have greater adverse impacts on ranges during a drought, and the recovery will be slower.

At the break in weather that occurs either sporadically during a drought or at its end, the pollutant concentration is greatly increased because the time between natural washings has been longer. This allows surface pollutants to build up more than in normal climatic conditions, resulting in higher concentrations in the first flush.

It should also be noted that surface impoundments reach normal levels much more rapidly than aquifers. This is because there is a delay caused by slow percolation of water to the groundwater table and because the very dry surface soils will adsorb water until they become saturated before allowing the water to pass. When the soils have been dry for extended periods, they can adsorb much more before becoming saturated (i.e., field capacity) than if they were relatively moist from a normal level of precipitation. Thus, even though precipitation levels have returned to normal, the effects of the drought on the groundwater table may linger. Also, it becomes more difficult to obtain compliance with conservation measures once there is normal precipitation, because the public is not aware of the lag time for aquifer recovery.

7 DEVELOPMENT OF AN INSTALLATION DROUGHT PLAN

Define Requirements and Assign Priorities

The first step in developing a drought plan is defining the various users' water requirements and assigning them allocation priorities during drought. Appendix B is a form for listing installation water uses to assign these priorities. The demands projected on this form should first be those for normal use; more forms can be used to develop water demand under different water conservation scenarios. The quantities listed on the forms should then be summed to determine the level of demand under each level of conservation.

Review Conservation Techniques

Appendix C outlines the levels of conservation suggested in this report. These levels are to be used to suggest initial techniques for various activities. Supply must be matched to demand during planning. Therefore, subsequent iterations of the plan may change the drought stage at which specific conservation techniques are instituted. General guidelines on the effect of conservation are shown in terms of percentage reductions based on normal seasonal use. The actual overall reduction in demand at a particular installation will be determined by the mix of its water uses. Under disaster conditions, all water use below Priority 1 must be eliminated, and some Priority 1 uses may need curtailing.

Estimate Available Water Supplies

The next step is to estimate available supply. Current supplies may have preset levels if the water supplier is an outside agency or if an outside agency controls the water rights of a surface stream or groundwater aquifer used by the installation. Available water can then be determined through the water supplier or agency that controls untreated water allocation. Water available from supply augmentation techniques (Appendix D) should be added to the water available from the normal supply. Total water available should then be compared to the remaining demand under each conservation strategy.

Review Demand Vs. Supply

If the comparison shows that water demand has been reduced insufficiently at a particular drought stage, the conservation measures must be made more stringent. Conversely, if the supply is more than sufficient for demand, less stringent conservation measures should be employed. Supply augmentation techniques may also be implemented at lower levels of drought to bring supply up to demand. Development of an overall plan is an iterative process during which installation personnel will identify all options prior to a drought and then implement the plan based on the estimates. Identifying all options also allows the installation to modify the plan as a drought progresses.

Estimate Water Demands

Initial development of the drought plan should pose a series of questions to all water users. Appendix E lists the typical questions that can be used for this purpose. This will generate an estimate of water demand to be recorded on the form in Appendix B. All water users should be given a copy of the information in Appendix C, with instructions to estimate the percentage reduction in water use that could be achieved using the stated conservation strategies. The numbers in parentheses at the top of the columns in Appendix C represent reduction goals. No goals are set for drought disaster, because this represents minimal use, which require substantial curtailment of activities, with water use only for equipment maintenance.

Coordinate With Appropriate Agencies

The purpose of the planning process is to identify potential actions that can be taken when an installation is faced with a drought. Water management systems available throughout much of the United States have been established to mitigate effects of uneven rainfall/recharge. The planning process must be coordinated with all agencies near the installation that control water management systems such as lakes, dams, and reservoirs. State environmental offices can provide the names of the responsible agencies. Further coordination should be implemented with adjacent water utilities, so that all water sources can be pooled to provide the best use of scarce resources.

8 SUMMARY

This report has outlined the most important aspects of developing a drought contingency plan for an Army installation. Installation personnel may use the general guidelines and checklists provided in Appendices B through E to develop methods of mitigating the effects of reduced water supplies according to their specific mission requirements and user needs.

The various stages of drought were defined to enable installations to recognize the degree to which their water supplies may be reduced and thereby most effectively implement conservation and augmentation strategies.

Depending on an installation's mission, location, and climate, several types of conservation and augmentation strategies may be used to cope with drought. The methods chosen will be a function of the individual installation's priorities. Some successful conservation methods used include metering, pressure regulation, rationing, flow-regulating devices, restriction or curtailment of various water-using activities, and price increases. Water supply augmentation methods that may be used include developing new wells, connecting with other surrounding water systems, building emergency dams, and cloud seeding.

The most important method of dealing with drought is development of a successful installation drought plan. Such a plan will provide a basis for estimating water requirements in emergency situations, assign water use priorities and allocate available water supplies accordingly, and employ conservation and augmentation strategies that are as economical as possible and well suited to the installation's needs.

REFERENCES

Alternative Drought Strategies for 1978 (State of California Governor's Drought Emergency Task Force, January 1978).

Before the Well Runs Dry, Volume II—A Handbook on Drought Management (American Water Works Association [AWWA], 1984).

Blackburn, Anne M., "Dealing with Drought, Management Strategies," *Water Conservation Strategies—An AWWA Management Resource Book* (AWWA, 1980).

Bruvold, W. H., "Residential Water Conservation: Policy Lessons From the Californian Drought," *Public Affairs Rept., Institute of Government Studies Bulletin*, Vol 19, No. 6 (University of California, Berkeley, CA, December 1978).

Dracup, John A., et al., "On the Statistical Characteristics of Drought Events," *Water Resource Res.*, Vol 16, No. 2, (April 1980), pp 289-296.

Dracup, John A., "Causes and Occurrences of Drought," *Drought Management and Its Impact on Public Water Systems* (National Academy Press, 1986).

Edmonds, L. A., and S. L. Bishop, "Planning for Droughts," *Consulting Engineer*, Vol 59, No. 3, (September 1982), pp 90-94.

Gerald, Sidney B., II, "Water Rationing on Okinawa," *Water Conservation Strategies—An AWWA Management Resource Book* (AWWA, 1980).

Harnett, John S., "Effects of the California Drought on the East Bay Municipal Utility District," *Water Conservation Strategies—An AWWA Management Resource Book* (AWWA, 1980).

Hrezo, M. S., et al, "Managing Droughts Through Triggering Mechanisims," *Journal of the American Water Works Association*, Vol 78, No. 6, (June 1986), pp 46-51.

Hudson, William D., "Increasing Water System Efficiency Through Control of Unaccounted for Water," *Water Conservation Strategies—An AWWA Management Resource Book* (AWWA, 1980).

Linsley, R. K., M. A. Kohler and J. L. H. Paulhus, *Hydrology for Engineers*, 2nd ed. (McGraw-Hill Book Company, 1975).

Maloney, S. W., R. J. Scholze and J. T. Bandy, *Preventing Water Loss in Water Distribution Systems: Money-Saving Leak Detection Programs*, Technical Report N-86/05/ADA167556 (U.S. Army Construction Engineering Research Laboratory [USA-CERL], 1986).

Miller, W. H., "Mandatory Water Conservation and Tap Allocations in Denver, Colorado," *Water Conservation Strategies—An AWWA Management Resource Book* (AWWA, 1980).

Morgan, W. D., and P. Pelosi, "The Effects of Water Conservation Kits on Water Use," *Water Conservation Strategies--An AWWA Management Resource Book* (AWWA, 1980).

New York State Drought Preparedness Plan (New York State Drought Management Task Force, February, 1981).

Rice, I. M., and L. G. Shaw, "Water Conservation--A Practical Approach," *Water Conservation Strategies—An AWWA Management Resource Book* (AWWA, 1980).

Russel, C. S., D. G. Arey, and R. W. Kates, *Drought and Water Supply* (John Hopkins Press, 1970).

Scholze, R. J., L. J. Benson, M. A. Kamiya, M. J. Staub, and J. T. Bandy, *Water Conservation Methods for U. S. Army Installations: Volume I, Residential Usage Management*, Technical Report N-146/ADA128550 (USA-CERL, 1983).

Scholze, R. J., L. J. Benson, M. A. Kamiya, M. J. Staub, and J. T. Bandy, *Water Conservation Methods for U. S. Army Installations: Volume II, Irrigation Management*, Technical Report N-146/ADA128516 (USA-CERL, 1983).

Sharpe, William E., "Water and Energy Conservation with Bathing Shower Flow Controls," *Water Conservation Strategies—An AWWA Management Resource Book* (AWWA, 1980).

Stone, Brian G., "Suppression of Water Use by Physical Methods," *Water Conservation Strategies—An AWWA Management Resource Book* (AWWA, 1980).

APPENDIX A:

MANUFACTURERS OF WATER-SAVING DEVICES

Aerators

Crest/Good Manufacturing Company, Inc. 325 Underhill Boulevard Syosset, NY 11791	(516) 920-7260
G&E Products, Inc. 2082 South Grand Avenue Santa Ana, CA 92705	(714) 540-3230
Key Marketing Corp. 21241 Ventura Blvd., Suite 266 Woodland Hills, CA 91364	(818) 999-1442
Melard Manufacturing Corp. 153 Linden St. Passaic, NJ 07055	(201) 472-8888
Metropolitan Water Saving Co., Inc. 5130 MacArthur Blvd. NW, Suite 106 Washington, DC 20016	(202) 363-1980
Ny-Del Corp. 740 E. Alosta Ave., P.O. Box 155 Glendora, CA 91740	(818) 335-2213
Speakman Company P.O. Box 191 Wilmington, DE 19899	(302) 764-7100
Wrightway Mfg. Co. 1050 Central Avenue Park Forest South, IL 60466	(312) 534-0500

Flow Restrictors

American Standard, Inc. 1 Centennial Plaza Secaucus, NJ 07094	(201) 980-3000
Crest/Good Manufacturing Company, Inc. 325 Underhill Boulevard Syosset, NY 11791	(516) 920-7260

Eaton Corporation Controls Division Plumbing and Heating Products 191 E. North Avenue Carol Stream, IL 60187	(312) 260-3400
G&E Products, Inc. 2082 South Grand Avenue Santa Ana, CA 92705	(714) 540-3230
Kohler Company Kohler, WI 53044	(414) 457-4441
Melard Manufacturing Corp. 153 Linden St. Passaic, NJ 07055	(201) 472-8888
Noland Co. 2770 Warwick Blvd. Newport News, VA 23607	(804) 428-9000
Ny-Del Corp. 740 E. Alosta Ave., P.O. Box 155 Glendora, CA 91740	(818) 335-2213
Speakman Company P. O. Box 191 Wilmington, DE 19899	(302) 764-7100
Water Control Equipment, Inc. Box 18203-MC Houston, TX 77023	(713) 371-9282
Western Water Conservation, Inc. 10880 Wilshire Blvd., Suite 1600 Los Angeles, CA 90024	(213) 879-5252
Woodward-Wagner Co. 4041 Ridge Avenue Philadelphia, PA 19129	(215) 226-4900
Wrightway Mfg. Co. 1050 Central Avenue Park Forest South, IL 60466	(312) 534-0500

Low-Flow Showerheads

American Standard, Inc. 1 Centennial Plaza Secaucus, NJ 07094	(201) 980-3000

Chatham Brass Co., Inc. 5 Olsen Avenue Edison, NJ 08817	(201) 494-7107
Eaton Corporation Controls Division Plumbing and Heating Products 191 E. North Avenue Carol Stream, IL 60187	(312) 260-3400
G&E Products, Inc. 2082 South Grand Avenue Santa Ana, CA 92705	(714) 540-3230
Key Marketing Corp. 21241 Ventura Blvd., Suite 266 Woodland Hills, CA 91364	(818) 999-1442
Melard Manufacturing Corp. 153 Linden St. Passaic, NJ 07055	(201) 472-8888
Metropolitan Water Saving Co., Inc. 5130 MacArthur Blvd. NW, Suite 106 Washington, D.C. 20016	(202) 363-1980
Wrightway Mfg. Co. 1050 Central Avenue Park Forest South, IL 60466	(312) 534-0500

Toilet Inserts

Baron Manufacturing Co. "Water Saver 105" 14439 N. 73rd St. Scottsdale, AZ 85260	(602) 955-7550
Chicago Specialty Manufacturing Co. 7500 Linder Avenue, Box 1022 Skokie, IL 60077	(312) 965-0035
Crest/Good Manufacturing Company, Inc. 325 Underhill Boulevard Syosset, NY 11791	(516) 920-7260
G&E Products, Inc. 2082 South Grand Avenue Santa Ana, CA 92705	(714) 540-3230
Key Marketing Corp. 21241 Ventura Blvd., Suite 266 Woodland Hills, CA 91364	(818) 999-1442

Metropolitan Water Saving Co., Inc. 5130 MacArthur Blvd. NW, Suite 106 Washington, D.C. 20016	(202) 363-1980
Ny-Del Corp. 740 E. Alosta Ave., P.O. Box 155 Glendora, CA 91740	(818) 335-2213

APPENDIX B:

ASSIGNING PRIORITIES AND ESTIMATING WATER DEMANDS*

Water Use Activity	Demand (gpm)	Priority (1-4)
Housing		
Family Housing	________	________
Barracks	________	________
Bachelor Officer Quarters	________	________
Visiting Officer Quarters	________	________
Mess Halls	________	________
Industrial		
Vehicle Washracks	________	________
Aircraft Wash	________	________
Steam Cleaning	________	________
Metal Plating and Finishing	________	________
Autoclaves	________	________
Boilers	________	________
Metal Cleaning	________	________
Paint Booth Water Wall	________	________
Air Pollution Wet Scrubbers	________	________
Laboratories	________	________
Cooling Towers	________	________
Dynamometers	________	________
Engine Test Cells	________	________
Ash-Handling Facilities	________	________
Industrial Laundries	________	________
Pesticide Management Area	________	________
Photographic Laboratory	________	________
Motor Pools	________	________
Administrative/Institutional		
Unclassified Office Space	________	________
Shipping and Receiving	________	________
Communications Facilities	________	________
Command-Level Headquarters	________	________
Radar Installations	________	________
Military Training and Instruction Facilities	________	________
Hospitals	________	________

*Adapted from *Before the Well Runs Dry, Volume II—A Handbook on Drought Management* (AWWA, 1984).

Commercial		
Commissary	________	________
Post Exchange	________	________
Gas Station	________	________
Laundromats	________	________
Restaurants/Cafeterias	________	________
Water Use Activity	**Demand (gpm)**	**Priority (1-4)**
Post Office	________	________
Bank	________	________
Irrigation		
Parade Grounds	________	________
Athletic Facilities	________	________
Golf Courses	________	________
Cemeteries	________	________
Lawns	________	________
Parks	________	________
Commercial Landscaping	________	________
Recreational		
Swimming Pools	________	________
Fire Demand (Determine from Army TM 5-813-6)		
________________	________	___1___
Unavoidable Loss (Estimate at 15 Percent of Average Day Flow If Unknown)		
________________	________	___1___
Other		
________________	________	________
________________	________	________
________________	________	________
________________	________	________
________________	________	________
________________	________	________

APPENDIX C:

IMPLEMENTATION OF CONSERVATION MEASURES BY DROUGHT STAGE

Conservation Measures	Drought Stage				
	Normal	Alert	Warning	Emergency	Disaster
I. Housing:			(10 percent reduction)	(20 percent reduction)	
- Pressure regulation.	Implement plumbing code	--	Identify service pressure	Reduce pressure in mains serving discrete housing units by partially closing valves	Install flow restrictors on services at the meter.
- Rationing:	Maintain consumption records	Update water allocation schemes	Activate water allocations schemes	More stringent allocations	Implement daily cut-off hours
-Flow-regulating devices	Update cost data	Consider selection and priorities	Implement installation program	Install free	--
-Water losses control:	Maintain metered ratio records	Implement leak detection program	Eliminate all surface leakage	Implement ground leak elimination	--
II. Industrial:			(10 percent reduction)	(20 percent reduction)	
-Consumption control	Fit meters	Monitor meters *periodically*	Investigate increases	Activate conservation plans	More stringent plans
-Water storage and distribution	Inspect	Upgrade	Eliminate leaks and losses	Throttle supplies	More stringent plans
-Machinery and vehicles	Identify use priorities	Reduce boiler cooling systems use	Install automatic cut-off when not in use	Activate reuse schemes; eliminate vehicle washing	Discontinue low-priority activities
III. Community:			(25 percent reduction)	(30 percent reduction)	
-Residential:	--	Activate conservation plans	Implement landscape irrigation rationing schemes	Eliminate swimming pool filling, landscape irrigation, car washing	More stringent control
-Commercial:	--	Activate conservation plans	Recycle cooling water	Restrict vehicle and building exterior cleaning	More stringent control
-Municipal:	--	Activate plans and alert public	Restrict water main and hydrant flushing	Discontinue and curtail other activities	--
IV. Irrigation:	Establish priorities for water needs	Reduce irrigation demands	(40 percent reduction) Implement irrigation management services	(60 percent reduction) Redistribute water to high-priority regions	Eliminate irrigation

APPENDIX D:

IMPLEMENTATION OF AUGMENTATION MEASURES BY DROUGHT STAGE

	Drought Stage				
Augmentation Measures	Normal	Alert	Warning	Emergency	Disaster
1. Extend use of surface supplies	--	Check	Divert	Pump out	Install field W.T. units
2. Extend use of reservoir water	--	Check	Pump out	Continue pumping to lowest intake level	Use raft-mounted pumps
3. Develop and drill wells	Maintain records	Monitor levels	Develop existing test wells	Drill new wells (particularly to increase production from low-permeability formations)	Drill deeper wells
4. Reactivate abandoned wells	Identify, evaluate	Check, test	Repair and use	Activate and pump	Activate and pump
5. Use emergency connections	Identify connected system's hydraulic head	Determine supply capability	Determine excess capacity	Use connection	Use connections
6. Negotiate/build new connections	Negotiate	Determine excess capacity	Build connections	Use connections	Use connections
7. Use other communities' connections	--	Identify connected system's hydraulic head	Determine supply	Use connection	Use Connections
8. Divert water from other uses	Determine priorities	Negotiate redistribution	Process legal aspects and update costs	Divert lowest priority	Divert and curtail other uses
9. Relaxation of dam flow release requirements	--	Negotiate relaxation	Request relaxation	Divert from upstream	Divert and curtail other uses
10. Build emergency dams	--	Identify, inspect, and evaluate possible sites	Design and update costs	Start building	Use storage
11. Reactivate abandoned dams	Identify, evaluate	Inspect	Assess effect on downstream users	Activate and use	Use storage

APPENDIX E:

TYPICAL QUESTIONS FOR ESTIMATING WATER USE AND CONSERVATION MEASURES

1. Golf course(s):

   a. Number of acres.

   b. Number of acres irrigated.

   c. Is potable water used?

   d. Describe existing irrigation system (automatic, manual, etc.).

   e. During which months is watering necessary?

   f. Is any other source of irrigation water available (such as a lake or quarry) close to the course?

   g. Daily, weekly, monthly use patterns.

   h. Use estimates.

2. Large cooling towers (water type) > 50 tons:

   a. Number.

   b. Number of tons capacity at each location (refrigeration shop records).

   c. Blowdown rate (gallons/ton/hour).

   d. Evaporation rate (gallons/ton/hour).

   e. Chemicals used.

   f. Months of use.

3. Landscape, athletic fields, parade grounds:

   a. Acreage presently irrigated.

   b. Daily, weekly, monthly use patterns.

   c. Use estimates.

4. Vehicle and aircraft washracks:

    a. Number of washracks.

    b. Number of vehicles.

    c. Number of washings/month/vehicle.

    d. Daily, weekly, monthly use patterns.

    e. Use estimates.

5. Steam cleaners:

    a. Number.

    b. Hours per week in use.

    c. Daily, weekly, monthly use patterns.

    d. Use estimates.

6. Metal plating and finishing:

    a. Daily, weekly, monthly use patterns.

    b. Use estimates.

    c. Pretreatment provided before discharge.

7. Boilers:

    a. Btu capacity.

    b. Months in use.

    c. Blowdown rate.

8. Autoclaves:

    a. Number and size.

    b. Hours per week use.

c. Daily, weekly, monthly use patterns.

d. Use estimates.

9. Paint booth water walls:

   a. Number.

   b. Daily, weekly, monthly use patterns.

   c. Use estimates.

10. Air pollution wet scrubbers:

   a. Type: spray, towers, cyclones, venturis, packed or floating beds.

   b. Daily, weekly, monthly use patterns.

   c. Use estimates.

11. Dynamometers:

   a. Number.

   b. Daily, weekly, monthly use patterns.

   c. Use estimates.

12. Industrial laundries:

   a. Number and capacity of washers.

   b. Daily, weekly, monthly use patterns.

   c. Use estimates.

13. Photo processing facility:

   a. Daily, weekly, monthly usage patterns.

   b. Use estimates.

   c. Pretreatment provided.

14. Civilian water users close to post:

    a. Golf course.

    b. Power plant.

    c. Agriculture.

    d. Others.

15. Other installation water-using activities:

    a. Description.

    b. Daily, weekly, monthly use patterns.

    c. Use estimates.

USA-CERL DISTRIBUTION

Chief of Engineers
ATTN: Tech Monitor
ATTN: DAEN-IMS-L (2)
ATTN: DAEN-CCP
ATTN: DAEN-CW
ATTN: DAEN-CWE
ATTN: DAEN-CWM-R
ATTN: DAEN-CWO
ATTN: DAEN-CWP
ATTN: DAEN-EC
ATTN: DAEN-ECC
ATTN: DAEN-ECE
ATTN: DAEN-ECR
ATTN: DAEN-RD
ATTN: DAEN-RDC
ATTN: DAEN-RDM
ATTN: DAEN-RM
ATTN: DAEN-ZCE
ATTN: DAEN-ZCF
ATTN: DAEN-ZCI
ATTN: DAEN-ZCM
ATTN: DAEN-ZCZ

FESA, ATTN: Library 22060
ATTN: DET III 79906

US Army Engineer Districts
ATTN: Library (41)

US Army Engineer Divisions
ATTN: Library (14)

US Army Europe
AEAEN-ODCS/Engr 09403
ISAE 09081
V Corps
ATTN: DEH (11)
VII Corps
ATTN: DEH (15)
21st Support Command
ATTN: DEH (12)
USA Berlin
ATTN: DEH (11)
USASETAF
ATTN: DEH (10)
Allied Command Europe (ACE)
ATTN: DEH (3)

8th USA, Korea (19)

ROK/US Combined Forces Command 96301
ATTN: EUSA HHC-CFC/Engr

USA Japan (USARJ)
ATTN: AJEN-DEH 96343
ATTN: DEH-Honshu 96343
ATTN: DEH-Okinawa 96331

416th Engineer Command 60623
ATTN: Facilities Engineer

US Military Academy 10966
ATTN: Facilities Engineer
ATTN: Dept of Geography &
Computer Science
ATTN: DSCPER/MAEN-A

AMMRC, ATTN: DRXMR-WE 02172

USA ARRCOM 61299
ATTN: DRCIS-RI-I
ATTN: DRSAR-IS

AMC - Dir., Inst., & Servc
ATTN: DEH (23)

DLA ATTN: DLA-WI 22314

DNA ATTN: NADS 20305

FORSCOM
FORSCOM Engr, ATTN: AFEN-DEH
ATTN: DEH (23)

HSC
ATTN: HSLO-F 78234
ATTN: Facilities Engineer
Fitzsimons AMC 80240
Walter Reed AMC 20012

INSCOM - Ch, Instl. Div
ATTN: Facilities Engineer (3)

MDW, ATTN: DEH (3)

MTMC
ATTN: MTMC-SA 20315
ATTN: Facilities Engineer (3)

NARADCOM, ATTN: DRDNA-F 01760

TARCOM, Fac. Div. 48090

TRADOC
HQ, TRADOC, ATTN: ATEN-DEH
ATTN: DEH (19)

TSARCOM, ATTN: STSAS-F 63120

USACC, ATTN: Facilities Engr (2)

WESTCOM
ATTN: DEH, Ft. Shafter 96858
ATTN: APEN-IM

SHAPE 09055
ATTN: Surv. Section, CCB-OPS
Infrastructure Branch, LANDA

HQ USEUCOM 09128
ATTN: ECJ 4/7-LOE

FORT BELVOIR, VA 22060 (7)
ATTN: Canadian Liaison Officer
ATTN: British Liaison Officer
ATTN: Australian Liaison Officer
ATTN: French Liaison Officer
ATTN: German Liaison Officer
ATTN: Water Resources Support Ctr
ATTN: Engr Studies Center
ATTN: Engr Topographic Lab.
ATTN: ATZA-DTE-SU
ATTN: ATZA-DTE-EM
ATTN: R&D Command

CRREL, ATTN: Library 03755

WES, ATTN: Library 39180

HQ, XVIII Airborn Corps
and Fort Bragg
ATTN: AFZA-FE-EE 28307

Area Engineer, AEDC-Area Office
Arnold Air Force Station, TN 37389

Chanute AFB, IL 61868
3345 CES/DE, Stop 27

Norton AFB, CA 92409
ATTN: AFRCE-MX/DEE

AFESC, Tyndall AFB, FL 32403

NAVFAC
ATTN: Engineering Command (7)
ATTN: Division Offices (6)
ATTN: Naval Public Works Center (9)
ATTN: Naval Civil Engr Lab. (3)

ATTN: Library, Code L08A NCEL 93043

Defense Technical Info. Center 22314
ATTN: DDA (2)

SETAF Engineer Design Office 09019

Engr Societies Library, NY 10017

Natl Guard Bureau Instl. Div 20310

US Govt Print Office 22304
Receiving Sect/Depository Copies (2)

US Army Env. Hygiene Agency
ATTN: HSHB-E 21010

National Bureau of Standards 20899

310
02/87

ENE Team Distribution

Chief of Engineers
ATTN: DAEN-ZCF-B
ATTN: DAEN-ZCF-U
ATTN: DAEN-ECZ-A

US Army Engineer District
New York 10007
ATTN: Chief, NANEN-E
ATTN: Chief, Design Br.
Pittsburgh 15222
ATTN: Chief, Engr Div
Philadelphia 19106
ATTN: Chief, NAPEN-E
Norfolk 23510
ATTN: Chief, NAOEN-D
Huntington 25721
ATTN: Chief, ORHED-H
Wilmington 28401
ATTN: Chief, SAWEN-PM
ATTN: Chief, SAWEN-E
Savannah 31402
ATTN: Chief, SASAS-L
Jacksonville 32232
ATTN: Env Res Br
Mobile 36628
ATTN: Chief, SAMEN-C
Vicksburg 39180
ATTN: Chief, Engr Div
Chicago 60604
ATTN: Chief, NCCCO-R
ATTN: Chief, NCCED-H
ATTN: Chief, NCCPD-ER
ATTN: Chief, NCCPE-PES
St. Louis 63101
ATTN: Chief, ED-D
Kansas City 64106
ATTN: Chief, Engr Div
Omaha 68102
ATTN: Chief, Engr Div
Tulsa 74102
ATTN: Chief, Engr Div
Fort Worth 76102
ATTN: Chief, SWFED-D
ATTN: Chief, SWFED-MA/MR
Galveston 77550
ATTN: Chief, SWGAS-L
ATTN: Chief, SWGCO-M
Los Angeles 90053
ATTN: Chief, SPLED-E
San Francisco 94105
ATTN: Chief, Engr Div
Sacramento 95814
ATTN: Chief, SPKED-D
Far East 96301
ATTN: Chief, Engr Div
Seattle 98124
ATTN: Chief, NPSEN-FM
ATTN: Chief, EN-DB-SE
ATTN: Chief, NPSEN-PL-WC
ATTN: Chief, NPSEN-PL-ER
Walla Walla 99362
ATTN: Chief, Engr Div
Alaska 99501
ATTN: Chief, NPASA-R

US Army Engineer Division
New England 02154
ATTN: Chief, NADEN-T
North Atlantic 10007
ATTN: Chief, NADEN-T
South Atlantic 30303
ATTN: Chief, SADEN-TE
Huntsville 35807
ATTN: Chief, HNDED-CS
ATTN: Chief, HNDED-ME
ATTN: Chief, HNDED-SR
Lower Mississippi Valley 39180
ATTN: Chief, PD-R
Ohio River 45201
ATTN: Chief, Engr Div
North Central 60605
ATTN: Chief, Engr Planning Br
Missouri River 68101
ATTN: Chief, MRDED-T
Southwestern 75242
ATTN: Chief, SWDED-TH
North Pacific 97208
ATTN: Chief, Engr Div.
South Pacific 94111
ATTN: Chief, SPDED-TG
ATTN: Laboratory
Pacific Ocean 96858
ATTN: Chief, Engr Div
ATTN: Chief, PODED-MP
ATTN: Chief, PODED-P

7th US Army 09407
ATTN: AETTM-HRD-EHD

US Army Foreign Science & Tech Center
ATTN: Charlottesville, VA 22901
ATTN: Far East Office 96328

USA ARRADCOM
ATTN: DRDAR-LCA-OK 07801

West Point, NY 10996
ATTN: Dept of Mechanics
ATTN: Library

Ft. Belvoir, VA 22060
ATTN: Learning Resources Center

Ft. Clayton Canal Zone 34004
ATTN: DFAE

Ft. A. P. Hill 24502
ATTN: FE

Ft. Leavenworth, KS 66027
ATTN: ATZLCA-SA

Ft. McPherson, GA 30330
ATTN: AFEN-CD

Ft. Monroe, VA 23651
ATTN: ATEN-AD
ATTN: ATEN-FE-E
ATTN: ATEN-FE-U

Aberdeen Proving Ground, MD 21005
ATTN: HSHB-MEW
ATTN: NGB-ARI-E

US Naval Oceanographic Office 39522
ATTN: Library

Naval Training Equipment Center 32813
ATTN: Technical Library

Bolling AFB, DC 20330
AF/LEEEU

Little Rock AFB
ATTN: 314/DEEE

Tinker AFB, OK 73145
2854 ABG/DEEE

Bldg Research Advisory Board 20418

Dept of Transportation
Tallahassee, FL 32304

Dept of Transportation Library 20590

Transportation Research Board 20418

END

9-87

DTIC